Factors influencing physical activity among individuals living with heart failure: a mixed-methods study

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DECLARATION

I, Aliya Amirova, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Signed: .... Date: ....

ABSTRACT

Heart failure (HF) is a complex clinical syndrome of symptoms and signs that suggest reduced efficiency with which the heart pumps blood around the body. HF is a prevalent condition worldwide and in the United Kingdom. The clinical outcomes of HF include mortality, morbidity, and reduced quality of life. Physical activity is beneficial to individuals with HF as it improves quality of life and reduces hospitalisation. However, its levels are exceptionally low in this population group. This suggests a need for supporting and encouraging behaviour change. The overall aim of this research is to extend understanding of how to promote physical activity among people with HF through systematic reviews and empirical research. Following the Medical Research Council guidance for developing complex interventions, first a meta-analysis of 16 randomised controlled trials evaluating physical activity was performed. The review identified a lack of understanding how best to increase physical activity in HF in older adults (>70 years old) who constitute the majority of the HF population. In a Bayesian meta-analysis of 28 observational studies the existing evidence on the relevant clinical, demographic, and psychosocial barriers and enablers to physical activity in HF was summarised. The review identified contextual factors that need to be considered when conducting research and developing behaviour change interventions. These were age, depression, and comorbidity. However, less is known about the modifiable factors that can be addressed in an intervention. A qualitative study using semi-structured interviews (N = 16) based on the Theoretical Domains Framework formulated 78 belief statements describing the barriers and enablers. Theoretical domains containing these beliefs and corresponding constructs that were both pervasive and common were deemed most relevant. These were: concerns about physical activity (*Beliefs about Consequences*), self-efficacy (*Beliefs about Capabilities*), social support (*Social Influences*), major health event (*Environmental Context and Resources*), goal behavioural (*Goal*), action planning (*Behavioural Regulation*) and (*Optimism*). A scale assessing these constructs was developed. Finally, computational modelling helped in assessing plausibility and providing grounds for model comparison. A power analysis and feasibility assessment are reported based on the model and the obtained N=3 sample.

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1 Introduction

1.1 Topic overview

Heart failure (HF) is a clinical syndrome resulting from any structural or functional cardiac disorder that leads to the reduction in the heart's ability to pump blood around the body (National Institute for Health and Care Excellence, 2010). HF is a common and increasing health problem; around 40 million people globally (Vos et al., 2016) and 558 000 people in the United Kingdom (Bhatnagar, Wickramasinghe, Williams, Rayner, & Townsend, 2015) are diagnosed with HF. The condition affects mostly older adults; the median age of a newly diagnosed person is 80 years old (National HF Audit, 2018). Despite advances in available medical treatment, high mortality rates, frequent hospital admissions, and poor quality of life persist (Hobbs et al., 2002; Taylor, Roalfe, Iles, & Hobbs, 2012).

Physical activity – '*any bodily movement produced by skeletal muscles that requires energy expenditure'* (World Health Organisation, 2018), such as exercise or walking –is associated with benefits for people with HF, including improved quality of life (Davies et al., 2010; Lewinter et al., 2015; Sagar et al., 2015; Taylor et al., 2014), reduced hospitalisation (Sagar et al., 2015; Taylor et al., 2014), and improved survival (Belardinelli, Georgiou, Cianci, & Purcaro, 2012; ExTraMATCH Collaborative, 2004). Given these benefits, the European Society of Cardiology (Ponikowski et al., 2016), American Heart Association and the National Institute of Health and Care Excellence (NICE) in the United Kingdom recommend that this clinical population engage in physical activity (McMurray et al., 2012; NICE, 2010; Yancy et al., 2013).

Increasing physical activity is recognised as an important aspect of HF treatment (NICE, 2010) and exercise is a major component of cardiac rehabilitation (CR) offered to individuals with HF (Jenni et al., 2012). Yet, everyday levels of physical activity in HF are low (Jaarsma et al., 2013); and the number of people with HF who start a cardiac rehabilitation programme is also low (British Heart Foundation, 2015).

To enhance levels of physical activity in people with HF, it is first important to understand the factors that influence engagement in physical activity in this population. The latter is addressed by the present line of research. The sections below outline the aim, research question and study objectives.

1.2 Aim

The overall aim of this research is to extend understanding of how to promote physical activity among people with HF through systematic reviews and empirical research.

1.3 Research question

- Are the current interventions effective in promoting physical activity in HF?
- What are the barriers and enablers to physical activity in HF?

1.4 Study objectives

The objectives of the study are (i) to evaluate the current evidence base for physical activity interventions in HF; to examine the impact of the interventions and to determine whether any particular characteristics of interventions are important in increasing physical activity; (ii) to determine through systematic literature review and empirical research what are the barriers and enablers to engaging physical activity in people with HF.

1.5 Research overview

To answer the research question, the present project employs a series of studies:

1. An examination of the existing literature on HF and physical activity:

a. A systematic review and meta-analysis of randomised controlled trials evaluating interventions designed to increase physical activity in HF.

b. A systematic review and meta-analysis of the barriers and enablers of physical activity in HF;

2. A mixed-methods study:

a. A qualitative study using semi-structured interviews designed to identify and describe perceived barriers and enablers to physical activity in HF;

b. A feasibility study designed to examine the acceptability and feasibility of administering an accelerometer and barriers and enablers to physical activity scale;

c. Computational modeling and model comparison of barriers and enablers to physical activity in HF.

Chapter 2 provides the context for this study by describing the clinical and epidemiological background of HF, including its pathophysiology and methods for diagnosis, its impact on health and quality of life, its economic burden, and the available treatments. Alongside this, physical activity and its role as a treatment strategy for HF are introduced: the operational definition of physical activity that will be used throughout the thesis; an overview of the evidence for the benefits and safety of physical activity in HF; and the current recommendations on physical activity for individuals with HF.

Chapter 3 outlines the conceptual framework underpinning this project. The study draws upon psychological theories of behaviour change to gain a better understanding of factors that act as the barriers and enablers to performing physical activity for people with HF. The Theoretical Domains Framework (Cane, O'Connor, & Michie, 2012) and Behaviour Change Taxonomy (Michie, 2013a), which inform this work, are described in Chapter 3. This chapter also describes the background to the methods used: meta-analysis and Bayesian framework.

1.6 Evaluating evidence-base

Chapter 4 reports a systematic review and meta-analysis of existing randomised controlled trials (RCTs) that aimed to increase physical activity in HF. The updated search

(January 2020) is reported in Appendix A. The overall aim of the review was to identify whether existing interventions or intervention components were efficacious in increasing physical activity in people with HF i.e. whether interventions or intervention components promoted (or hindered) engagement in physical activity. The specific objectives were to (i) evaluate the efficacy of intervention(s) that aimed to increase physical activity in people with HF and (ii) identify intervention characteristics that contributed to efficacy in increasing physical activity.

The review identified that, overall, the existing physical activity interventions did not yield an impact on physical activity that takes place outside an intervention after the intervention has been completed[1]. The lack of efficacious interventions indicates that further research is required to identify how best to increase physical activity in HF.

1.7 Determining barriers and enablers

Chapter 5 presents a Bayesian meta-analysis of barriers and enablers to physical activity in HF. The aim of the review was to summarise the existing evidence on the relevant clinical, demographic, and psychosocial barriers and enablers to physical activity in HF. The specific objectives were to i) identify and describe and to ii) compare clinical, demographic, psychosocial barriers and enablers to physical activity in HF.

Age, comorbidity, and negative attitude were identified as barriers to physical activity in HF by both qualitative and quantitative studies. However, less is known about other potential contextual and modifiable determinants of physical activity in HF.

The findings of these two reviews indicated that further research was required to better understand the factors that influence engagement in physical activity by people with HF. To

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[1] The meta-analysis of the updated search (2020) is included in the Appendix A

further investigate these factors, an exploratory sequential mixed-methods study was designed to identify and describe barriers to and enablers of physical activity in HF (Appendix N). The study consisted of a qualitative phase using semi-structured interviews, followed by a quantitative phase assessing physical activity, using triaxial accelerometer, and barriers and enablers to the behaviour, using self-reports. The qualitative phase informed the design of the quantitative phase. As such, the self-reports (i.e. validated questionnaires and supplementary scales) were chosen based on the findings of the qualitative phase. The findings of the first, qualitative, phase of the mixed methods study also defined the hypotheses to be tested in the second, quantitative phase of the study.

Chapter 6 presents a qualitative semi-structured interview study (Phase 1). The aim of the qualitative phase was to identify perceived barriers to and enablers of physical activity in people with HF. The objectives were to (i) conduct semi-structured interviews with 16 older adults with HF, (ii) to analyse the interview transcripts to identify perceived barriers to and enablers of physical activity in HF, and (iii) to inform the selection of questionnaire measures to be used in the quantitative phase of the study. This research study employed the Theoretical Domains Framework (TDF), (Cane, O'Connor, & Michie, 2012; Michie et al., 2005) to explore a comprehensive range of theoretical domains and constructs that may act as barriers to or enablers of physical activity in HF.

Overall, the qualitative study formulated belief statements, psychosocial constructs, and causal representations that affect physical activity behaviour in HF. The qualitative findings suggested the relevance of the following models: the MB-MF-Pavlovian (Dayan & Berridge 2014; Zhang et al., 2009), Health Action Process Approach (Schwarzer, 2008), and an auxiliary model. The auxiliary model was distinguished from HAPA by the lack of the relevance of risk perception. Instead it highlights the role of major-health event and goal (behavioural) in the context of HF.

Chapter 7 presents a model outlining processes underlying physical activity in HF and a scale assessing the determinants of physical activity in HF (Phase 2). The aim of the quantitative phase of this research was to model the relationship between potential enablers and barriers as predictors of physical activity levels. This included (i) content development for a scale assessing barriers and enablers to physical activity in HF (ii) computational modelling of barriers and enablers of physical activity in HF based on the qualitative semi-structured interviews' findings; (iii) a power analysis and feasibility assessment for a cross-sectional study assessing behavioural determinants and physical activity (accelerometry).

2 Background to HF and Physical Activity in HF

To place this research in context, this chapter provides a brief overview of HF condition as well as a summary of its impact on health and quality of life, the economic burden, and available treatments. This is followed by a summary of the current recommendations for physical activity in HF and the potential role physical activity can play in its treatment.

2.1 Definition and symptoms of HF

HF is a clinical syndrome resulting from any structural or functional cardiac disorder that impairs the ability of the heart to support physiological circulation (National Clinical Guideline Centre, 2010). The typical symptoms of HF include breathlessness, fatigue, reduced exercise tolerance, and retention of fluid in the lungs and in peripheral parts of the body (i.e. ankles and feet). HF is a progressive condition which starts from asymptomatic alterations in cardiac structure and function, then evolves to overt symptoms, increased risk of disability, restricted independence, and death (Hunt, 2005). At early stages of HF, breathlessness and fatigue can be experienced only on exertion; at later stages these symptoms can be present at rest.

2.2 Physiology of the heart

The heart consists of four chambers: right and left atria and right and left ventricles (Figure 2.1).

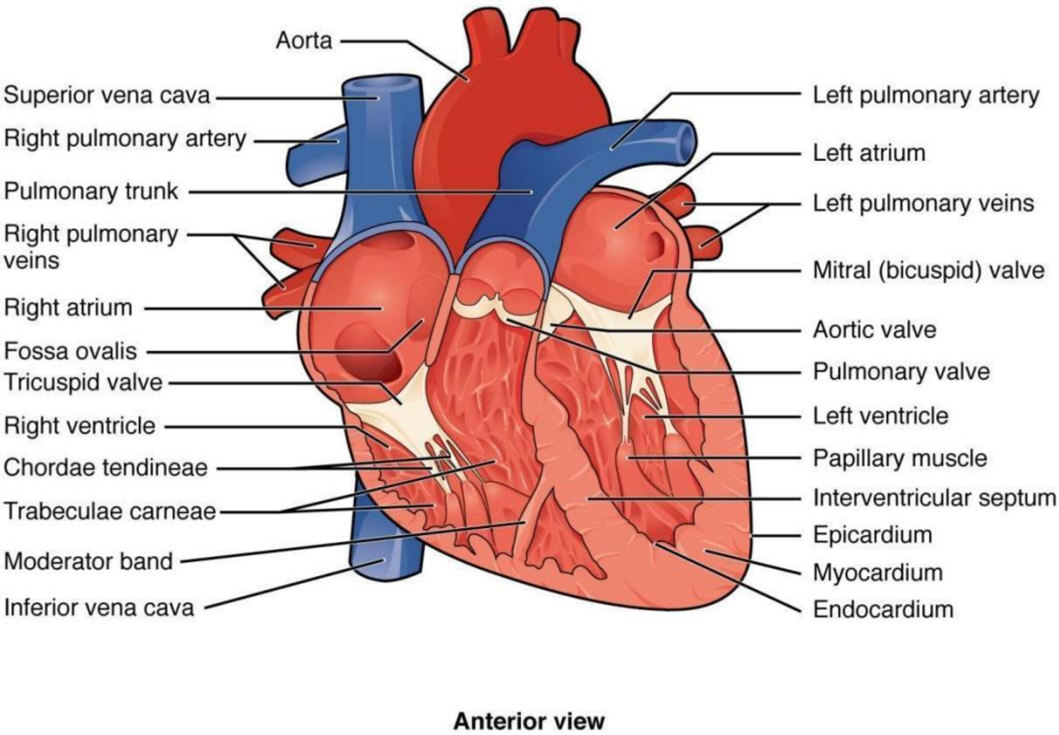

Figure 2.1. The sectional anatomy of the heart .Image from OpenStax College (2013).

The cardiovascular system is arranged in such a way that blood flows from low to high pressure. The heart functions as a pump and fills with blood at low pressure during the first phase (diastole) and then contracts, generating high pressure, to eject blood during the second phase (systole). The right ventricle accepts deoxygenated blood from the body and pumps it through pulmonary vasculature at the diastole, and then the left ventricle receives oxygenated blood and pumps it into the systemic circulation at systole Figure 2.1.

The coordinated pumping action of the chambers is controlled by an electrical system that is contained in the heart muscle. The normal heartbeat is stimulated by an electrical signal that originates in a region of the right atrium known as the sinoatrial or SA node. The electrical signal then spreads through both atria, causing them to contract and squeeze blood into the ventricles. The electrical signal then passes through an electrical control station known as the atrioventricular or AV node. After a split-second delay, the signal spreads to the ventricles by way of specialized routes called the left and right bundle branches. The bundle branches fan out in the ventricles, thereby enabling the electrical signal to stimulate both ventricles to contract simultaneously. This simultaneous, coordinated contraction of the ventricles is necessary for optimal pumping of blood to the body and lungs.

The overall performance of the heart is considered in terms of stroke volume (the blood volume ejected in one beat), cardiac output (the blood volume ejected in one minute), and left ventricular ejection fraction (LVEF, %). LVEF is the fraction of blood volume at the end of the diastole that is ejected to the body during each contraction of the heart. The LVEF of the normally functioning heart is between 50% and 70% (Roger, 2010).

2.3 Pathophysiology of HF

Various cardiac conditions, such as high blood pressure (hypertension), clogging up of the vessels supplying the heart with blood (coronary heart disease), heart muscle weakness (cardiomyopathy), and disturbance in cardiac rhythms (arrhythmia) as well as alcohol abuse can result in either systolic or diastolic dysfunction with reduced ventricular filling and reduced myocardial contractility. This leads to the development of chronic HF syndrome.

In HF, the pumping function of the heart is impaired at systole or diastole or both. This leads to reduced LVEF (%) and inability to supply an adequate amount of blood to the system to meet the metabolic demands of the body (Piano, Bondmass, & Schwertz, 1998). This leads to the development of symptoms such as water and sodium retention and breathlessness.

A LVEF of 35% to 50% is considered mild dysfunction, a LVEF <35% is considered moderate dysfunction, and a LVEF<20% is considered severe systolic dysfunction (Roger, 2010). HF due to left ventricular systolic dysfunction (HFrEF) is the impairment in the ability of the heart to pump blood during systole. HF can also occur in patients with normal left ventricular systolic function in whom higher filling pressure is needed to obtain a normal end-diastolic volume of the left ventricle, so called HF with preserved left ventricular ejection fraction (HFpEF).

2.4 Diagnosis of HF

The symptoms present upon physical examination form the basis for the HF diagnosis. However, these symptoms are non-specific and may be associated with several conditions and thus do not differentiate HF (Oudejans et al., 2011) For example, symptoms resulting from water and sodium retention are also experienced in thyroid and kidney diseases. It is especially difficult to detect HF in obese individuals, older adults, and those suffering chronic lung diseases. Therefore, the investigation of underlying cardiac cause and the medical history of preceding conditions are central to diagnosis of HF (McMurray et al., 2012; National Clinical Guideline Centre, 2010) National Institute for Health and Clinical Excellence, 2010). NICE guidelines (2010) the following steps for establishing the diagnosis of HF:

a) Evaluation of the structure and diastolic and systolic function, heart rhythm and heart rate using echocardiography (ECG). Echocardiography (ECG) is a cardiac ultrasound imaging technique that provides information about cardiac anatomy (volumes, geometry, mass) and function (left ventricular function and wall motion, valvular function, right ventricular function, pulmonary artery pressure, pericardium) (McMurray et al., 2012).

b) Measurement of the blood concentration of natriuretic peptides. Natriuretic peptides are hormones, the secretion of which is increased when the heart is diseased. The concentration thresholds of two hormones are used to eliminate HF: B-type natriuretic peptide (BNP) and N-terminal pro B-type natriuretic peptide (NT-proBNP).

c) Exclusion of other causes of abnormal levels of natriuretic peptides (e.g. renal failure).

d) Investigation of the precipitating cardiac conditions (e.g. myocardial infarction).

1.1 Symptomatic severity of HF

The New York Heart Association (NYHA) is used to grade the severity of HF (NICE, 2010). NYHA class is a subjective judgement a clinician makes about symptom severity, medical history, and limitations in physical activity due to HF (e.g. signs of exertion present at physical examination). Individuals within NYHA class I have no limitations in performing an ordinary physical activity task, and does not experience symptoms attributed to HF (i.e. undue breathlessness, fatigue or palpitations). Whereas individuals within classes II, III have mild and moderate limitations to performing physical activity, which results in slight and marked undue breathlessness, fatigue or palpitations, respectively. Individuals in NYHA class IV are unable to carry out any physical activity without experiencing discomfort, which is increased if any activity is undertaken; and experience undue breathlessness, fatigue or palpitations at rest (NICE, 2010).

An individual who has not experienced changes in NYHA class and has had no change in their pharmaceutical treatment regimen for at least a month is defined as having stable HF (McMurray et al., 2012; National Clinical Guideline Centre, 2010).

2.5 The course of HF

As cardiac function decreases, the heart uses three major compensatory mechanisms to maintain an adequate LVEF: increased sympathetic nervous system activity (Eisenhofer et al., 1996) increased contractility of the muscle and subsequent increase in muscle stiffness (Maestrini, 1951) and ventricular hypertrophy – the thickening of ventricular walls due to increased blood supply to the myocardium (Hein et al., 2003). These mechanisms maintain cardiac performance for a short period of time, but have a long-term negative impact on the individual's health and functioning. These physiological changes put strain on the heart and result in further deterioration of cardiac function. Thus, the pathophysiology described above results in progression of HF over time.

2.6 Epidemiology of HF

HF is a major public health problem affecting 40 million people globally (Vos et al., 2016) and 558 000 people in the United Kingdom (Bhatnagar, Wickramasinghe, Williams, Rayner, & Townsend, 2015). Improvements in the treatment of myocardial infarction and prevention of sudden cardiac death have led to an increase in the incidence of chronic HF (Lloyd-Jones et al., 2002). The condition affects mostly older adults; the median age of a newly diagnosed person is 80 years old (British Heart Foundation, 2015).

The incidence of HF is twice as high in men as in women of all age groups (Mehta & Cowie, 2006). The national audit estimated that in 2015 the median age of a person with HF was 80 years across genders/sexes, but slightly higher for women and lower for men (British Society for HF, 2015). There were more men in each age category except for the 85+ age group where women were in the majority.

2.7 Mortality in HF

The largest prospective study on the mortality in HF suggested that the 5-year survival rate among individuals diagnosed with HF is markedly reduced compared to the general population, 53% versus 93%, respectively (Echocardiographic Community Heart of England

Screening Trial, ECHOES, Hobbs et al., 2007) . At the 10-year follow-up of the same cohort, a total of 2062 (33.5%) out of 6162 individuals with HF had died (ECHOES Taylor et al., 2012). This suggests a poor long-term survival rate. In this study, diabetes, valvular disease, smoking, and obesity were associated with increased risk of death (Taylor et al., 2012). The National HF audit counted 56915 deaths in 2015, which is a 4% increase from the last audit (The British Society for HF, 2015).

2.8 Hospitalisation in HF

HF is a chronic condition and bouts of worsening of the symptoms are common. The rapid occurrence of severe symptoms leads to hospitalisation. HF hospitalisation accounts for around 5% of all emergency admissions to hospital and for about 2% of all inpatient days in the UK (National Clinical Guideline Centre, 2010) According to the National HF Audit, 134,044 people with HF were admitted to hospital in 2015 (British Society for HF, 2015). The median length of hospital stay was 9 days for those admitted to Cardiology wards and 7 days for those in General Medicine (British Society for HF, 2015). The rehospitalisation rate, which is estimated at 50% within the first three months of discharge from hospital and imposes an economic burden on the National Health Service (NHS), that is estimated to be around £716 million in 2035 (Petersen, Rayner, & Wolstenholme, 2002). General practitioners' consultation and outpatient clinic referrals cost the NHS around £80 million a year, While outpatient drug therapy costs are estimated at £129 million a year (Berry, Murdoch, & McMurray, 2001).

2.9 Treatment of HF

The aim of HF treatment is to reduce the frequency of hospitalisation and improve survival and quality of life as postulated by the NICE guidelines (2010). Timely measures such as lifestyle changes, pharmaceutical treatment, and invasive procedures as outlined below are recommended to reduce the long-term negative consequences of compensatory mechanisms and thus prevent further progression of the condition (Hunt, 2005). Pharmaceutical management of HF comprises diuretics, aldosterone antagonists, angiotensin-converting enzyme (ACE) inhibitors, beta-blockers, and inotropic agents (NICE

2010). The medication regimen of individuals with HF is complex and is often further complicated by the pharmaceutical management of comorbid conditions, including diabetes, ischemic heart disease, atrial fibrillation and high blood pressure. According to a large survey on the quality of care among 11304 patients admitted for HF in 24 European countries, 44.6% of the population takes four or more drugs (Komajda et al., 2003). Invasive procedures are performed to treat severe HF and include implantable devices, surgery, and organ transplantation. These procedures are considered when HF symptoms persist despite taking up pharmaceutical treatment (McMurray et al., 2012; Yancy et al., 2013)

As part of the effort to manage HF more effectively, and to reduce adverse events as well as the frequency of hospitalisation, people with HF are also recommended to lead a healthy lifestyle: to reduce alcohol and salt intake, cease smoking and to maintain physical activity (NICE, 2010). These recommended behaviours constitute self-care for a person living with HF. albeit, these self-care behaviours are poorly performed (Jaarsma et al., 2013) and often compromised by complex medication regimens. This research focuses on physical activity as one of the self-care behaviours and an important aspect of HF treatment. The operational definition of physical activity used herein is provided below.

2.10 Definition of physical activity

This thesis adopts a broad definition of physical activity as “any bodily movement produced by skeletal muscles that requires energy expenditure” (WHO, 2018). However, the behaviour is specified for each study as described below.

Exercise is a subset of physical activity defined as structured physical activity (WHO, 2018). Physical activity can be classified as occupational and leisure-time physical activity (Division of Nutrition, Physical Activity, and Obesity, 2015).

Physical activity types include aerobic, muscle-strengthening, bone-strengthening, and stretching. Physical activity can also be categorised in terms of mode, intensity and duration.

Modes of physical activity include, for example, sports, conditioning exercises, household tasks (e.g. gardening), walking, and running. The levels of intensity are: sedentary (a metabolic equivalent of task, MET of one), moderate (MET of 3-6) , and vigorous (MET >6). One MET is 1 kcal/kg/hour and is expended when sitting quietly. Hence, moderate activity describes expenditure of sixfold of that, and vigorous – over sixfold.

2.11 Benefits of physical activity for people with HF

2.11.1 Effects of physical activity on exercise capacity in HF

Exercise intolerance, defined as reduced ability to perform physical activity due to breathlessness and fatigue is a challenging symptom and operationalized as a reduction in exercise capacity and measured using maximum oxygen uptake (VO2max) – the amount of oxygen utilised by an individual While performing an aerobic exercise. Exercise capacity is a strong predictor of morality and hospitalization risk in HF.

The induced increase in exercise capacity because of aerobic exercise leads to reduction in fatigue, breathlessness, and positive outcome in terms of functional capacity for patients with HF due to left ventricular dysfunction (Downing, Balady, 2011). Various mechanisms through which physical activity impacts exercise capacity have been proposed. Aerobic exercise induces left ventricular remodelling, and thereafter increases left-ventricular ejection fraction, reverses endothelial dysfunction, skeletal muscle wasting and ventilator inefficiency which leads to improvement in exercise capacity (Chicco et al., 2008; Papathanasiou et al., 2008). Inactivity, on the other hand, leads to reduced exercise capacity, physical deconditioning, which causes worsening of HF symptoms and reduced exercise capacity (McKelvie et al., 1995).

Maintenance of physical activity in the long-term is advised, as it prevents physical deconditioning and subsequent decline of functional capacity (Pina et al., 2003). Physical activity inhibits pathologic cardiovascular remodelling, promotes physiologic remodelling, and improves cardiac, neurohormonal, skeletal muscle, pulmonary, renal, and vascular performance (Nayor et al., 2015).

A meta-analysis of 47 studies evaluating effects of exercise programmes suggests that high-intensity exercise may elicit the greatest change in exercise capacity (V02max) of HF patients (Ismail et al (2014). In the largest up-to-date randomised controlled trial, 2331 individuals with HF (72% men, mean age 59 years) with LVEF ≤ 35%, in the New York Heart Association functional class II–IV, and under optimal medical treatment, were randomized to either the training group (36 sessions of supervised, moderate-intensity training followed by home-based training) or the usual care group. HF-ACTION (O'Connor et al., 2012) highlights the importance of the levels of physical activity by demonstrating that greater amount of exercise resulted in a greater change in exercise capacity.

2.11.2 Effects of physical activity on mortality in HF

Large-scale observational studies have suggested an association between exercise and low rates of all-cause mortality in the general population (Byberg et al., 2009; Wen et al., 2011). A recent meta-analysis of 33 Randomised Controlled Trials (RCTs) evaluated the effects of exercise-based CR on mortality (Sagar et al., 2015). The review found that there was no significant difference in the survival rate between usual care and exercise programmes at 12 months follow-up (Sagar et al., 2015). However, the authors suggested that there was a trend towards improvement in the survival rate in the exercise group. Currently, research on the association between health benefits and the duration of the exercise programme is not conclusive. A unique study investigating the effects of a prolonged exercise programme demonstrated that the risk of death due to HF was significantly reduced for individuals attending an exercise programme twice a week for 10 years compared to control group, hazard ratio: 0.68, $p < 0.001$ (Belardinelli, Georgiou, Cianci, & Purcaro, 2012). The prolonged duration of the exercise programme and the high attendance rate (88%) in the 10-year trial may have confounded the effect of exercise programme on mortality. These factors have not been present in most short programmes included in the meta-analysis (Sagar et al., 2015). Overall, the evidence suggests that physical activity may result in the reduction in mortality risk, when maintained consistently and long-term.

A meta-analysis, based on individual patient data of RCTs compared exercise training with usual care and included a total of 801 patients, 395 in the exercise programme and 406 in the control group (ExTraMATCH Collaborative, 2004). The average follow-up was 705 days and the duration of the programme ranged from 84 to 420 days. Overall, there were 88 deaths in the exercise arm (median time to event, 618 days) and 105 in the control arm (421 days). The ExTraMATCH meta-analysis therefore provided evidence suggesting that survival rate as well as survival time is significantly extended for individuals assigned to an exercise programme (ExTraMATCH Collaborative, 2004).

2.11.3 Effects of physical activity on hospitalisation in HF

In a meta-analysis of 33 trials, hospitalisation due to HF has been found to be reduced at a 1-year follow-up after an exercise training programme compared with a no exercise control (Taylor et al., 2014).However, the effect was not maintained at follow-up beyond that period (Sagar et al., 2015). On the other hand, a 10-year consistent exercise programme has resulted in the reduction of hospitalisation due to HF at the 5-year follow-up (Belardinelli et al., 2012). This suggests that maintaining physical activity for a long period of time is required for the hospitalisation rate to be reduced in the long-term.

2.11.4 Effects of physical activity on quality of life in HF

Quality of life has been found to improve following exercise training programmes compared with no exercise control in all meta-analyses of exercise programmes (Taylor et al., 2014; Lewinter et al., 2015; Sagar et al., 2015). Exercise programmes had a positive effect on quality of life as compared to usual care at 12-month follow-up and beyond (Sagar et al., 2015). Supervised aerobic exercise training for 63 individuals has resulted in significantly improved quality of life (QoL) at the 12-month assessment in comparison to the non-training control group (n=60) (Bellardinelli et al., 2000; Bellardinelli et al., 2005). These effects were sustained at 10-year follow-up assessment. However, the adherence rate to the exercise was high (88%) throughout the 10-year study period (Bellardinelli et al., 2012). In summary, maintained exercise throughout a long period of time may result in a sustained benefit in terms of quality of life.

2.11.5 Physical activity recommendation in HF

Alongside lifestyle recommendations, including restricted salt and alcohol intake and smoking cessation, individuals with HF are advised to engage in physical activity (NICE, 2010). The European Society of Cardiology Guidelines (Ponikowski et al. 2016) for the diagnosis and treatment of chronic HF have stated a recommendation (class IA[2]) for regular aerobic exercise to improve functional capacity and HF symptoms (McMurray et al., 2012). Recommendations include exercise programme and lifestyle changes, including promotion of unspecified everyday physical activity (McMurray et al., 2012; Yancy et al., 2013). The recommendations on intensity and duration of physical activity vary and, given the lack of a prescription, an individualized approach is recommended (Pina et al., 2003).

However, physical activity was emphasised as safe and recommended to individuals with chronic stable HF for the first as recent as 2003 (NICE, 2003). Ever since then, regular physical activity is recommended to medically stable individuals with HF in NYHA classes I to III (Yancy et al., 2013; NICE, 2010; McMurray et al., 2012). Before that it was erroneously advised to restrict physical activity if diagnosed with HF. Therefore, popular opinion among the public may vary and individuals with HF are not necessarily aware of the safety and benefits of physical activity in HF. In addition, physical activity is not recommended to individuals with severe, acute, or decompensated HF. Which may add more complexity to adhering to the physical activity recommendation when HF becomes chronic and stable.

[2] 1 Class I: Evidence and/or general agreement that a given treatment or procedure is beneficial, useful and effective. A: the supporting data is driven from multiple randomized controlled trials.

2.12 Physical activity as a treatment strategy in HF

2.12.1 Cardiac rehabilitation and exercise-based programmes

Physical activity in the form of supervised exercise is offered as part of routine care for individuals with HF, including Cardiac Rehabilitation (CR) and exercise programmes. CR services aim to facilitate physical, psychological, and emotional recovery and to enable referred individuals to achieve and maintain better health (British Heart Foundation, n.d.). This is thought to be achieved through education, personalised information, exercise, relaxation, support, and opportunities for discussion throughout people’s care to help them understand their condition and be involved in its management, and meet their psychological needs (NICE, 2016) National guidelines consistently recommend CR to medically stable individuals with HF without any precluding conditions (McMurray et al., 2012; Yancy et al., 2013).

Individuals with HF may experience difficulties in their performance of activities of daily living due to frailty (Norberg, Boman, & Löfgren, 2008). Frailty is defined as a distinctive health state resulted from the ageing process in which multiple body systems gradually lose their reserve (British Geriatrics Society, 2014). Reducing frailty and maximizing functioning and independence in older individuals with HF is an important treatment goal, which can be achieved by increased daily physical activity (Witham, Argo, Johnston, Struthers, & McMurdo, 2006).

2.12.2 Implementation of cardiac rehabilitation

The number of individuals with HF who are referred to CR is very low (Beswick et al., 2004). Fewer than 20% of individuals with HF across Europe participate in CR programmes (Bjarnason-Wehrens et al., 2010). While the cardiac population who do participate, do not attend the programme as recommended (Jolliffe et al., 2001).

Adherence has been defined as the extent to which a person's behaviour – taking medication, following a diet, or executing a lifestyle change – corresponds to the recommendations of a healthcare provider (Sabate, 2003). Exercise adherence is also defined as the extent to which a person acts in accordance with the advised interval, exercise dose and exercise dosing regimen (Conraads et al., 2012).

The adherence to exercise programmes is low; only 35% of exercise programme participants complete 36 weeks of the programme and only 40% of those engage in the prescribed 90-minute weekly sessions (Keteyian, Ellis, & Houston Miller, 2009).

In the United Kingdom, only 3794 people with HF started CR in 2013-2014, which is 5.9% of newly diagnosed individuals in that year and 0.73% of those living with HF (British Heart Foundation, 2015). Most CR programmes in the UK are hospital-based (Thompson, Bowman, Kitson, de Bono, & Hopkins, 1997) which poses logistics difficulties. It involves traveling to the hospital which may be difficult for a frail and ill older adult with HF. Several of the barriers to attending CR are speculated to exist at the system level (i.e. socio-economic factors, limited availability of cardiac rehabilitation programmes and exercise programmes) and the physician level (i.e. low referral and logistics difficulties), as outlined in a consensus paper on adherence to exercise programmes and its barriers (Conraads et al., 2012).

Given the barriers to attending CR and exercise programmes, to reap the health benefits associated with physical activity it is important that individuals with HF engage in unstructured physical activity of a preferred mode and intensity, including leisure or household activity. Unstructured physical activity may be easier to fit into every-day life than a structured exercise programme (Conraads et al., 2012). This is especially relevant given the complex management regimen of an individual with HF.

2.13 Unstructured everyday physical activity

The unstructured everyday levels of physical activity that takes place outside CR or other exercise-based programmes is the target behaviour of this thesis. The levels of such physical activity are also low. A large secondary analysis of a large Biobank dataset suggests that the levels of both, self-reported and measured using accelerometer, physical activity are significantly lower in those diagnosed with HF (N=16 000) than in individuals without HF (N=387 580) (O'Donnell et al., 2020).

This thesis is concerned with all types, modes, and intensity of physical activity that takes place outside an exercise programme. However, the primary outcome of physical activity will be stratified in terms of the mode (e.g. walking, gardening) and intensity (moderate-vigorous physical activity, MVPA).

2.14 Target behaviour

It is recommended to specify the target behaviour in specific terms (Fishbein et al., 1967; French et al., 2012; Michie et al., 2014; Araujo-Soares et al., 2018). This means that a detailed description of who needs to do what differently, when, where, how often and with whom should be provided (Michie et al., 2014). For HF, Conraads et al. (2012) specify that any type and mode of physical activity should be performed as frequently as possible to improve clinical outcomes. They also advise that physical activity should be performed in a setting and mode and type as preferred by the individual living with HF. It is unclear what the specific target physical activity should be, as Conraads et al. (2012) advise future research must be done to investigate physical activity preferences held by people living with HF.

2.15 Conclusion

Physical activity is a treatment strategy strongly recommended to individuals with stable HF and offered alongside pharmaceutical treatment in the form of an exercise programme or CR. It is important to maintain a reasonable level of physical activity to maintain physical function, independence of an individual living with HF and to reduce their level of frailty. Physical activity has also been found to be associated with reduced mortality, hospitalisation, and improvements in quality of life. National Guidelines on HF management recommend that individuals diagnosed with HF should be routinely offered: (i) cardiac rehabilitation that targets lifestyle changes including physical activity and (ii) a physical exercise programme, yet the implementation of these programmes for individuals with HF is poor. Given the poor implementation of CR and the barriers to attending CR and exercise programmes outlined in this chapter, the present study recognises that in order to attain health benefits associated with exercise it is important to develop additional means to support an individual with HF in engaging in physical activity. Yet, the levels of physical activity in HF are also low. Therefore, this thesis is focused on how to improve the levels of physical activity in HF.

3 Conceptual Framework

Physical activity is beneficial to individuals with HF (Taylor et al., 2014; Sagar et al., 2015; Belardinelli et al., 2012). However, its levels are exceptionally low in this population group (Jaarsma et al., 2013). This suggests a need for supporting and encouraging behaviour change. Such change can be realised through the development and implementation of a behaviour change intervention (BCI), defined as ‘coordinated sets of activities designed to change specified behaviour patterns’ (Michie, van Stralen, and West, 2011). The National Institute for Health and Care Excellence (NICE; 2010) guidelines for behaviour change recommend that all BCIs should be developed and evaluated in stages, using an established approach such as the one recommended by the Medical Research Council guidance for the development and evaluation of complex interventions (MRC; Craig et al., 2008).

Evidence-based and theoretically underpinned interventions are thought likely to bring about behaviour change (Araújo-Soares, Hankonen, Presseau, Rodrigues, & Sniehotta, 2019; Craig et al., 2008; Hankonen & Hardeman, 2020; Kok et al., 2016; S Michie, Atkins, & West, 2014; O’Cathain, Croot, Sworn, et al., 2019).Therefore, the MRC guidance recommends careful consideration of behaviour change theory and evidence for the development of interventions before they can be experimentally assessed. It is recommended to draw on existing evidence and perform new empirical research as necessary (Craig et al., 2008).

Only one existing RCT, as identified by the systematic review reported in Chapter 4, evaluated a theory-based intervention targeting *self-care behaviours in general*, one of these behaviours is physical activity engagement (REACH-HF; Dalal et al., 2018). REACH-HF was the first research programme that followed the MRC guidelines in developing interventions designed to improve self-care behaviours in HF. However, the efficacy of the REACH-HF intervention in increasing *physical activity* in HF was not supported (Dalal et al., 2018). No power calculations or sample estimation were carried out which limits confidence in drawing conclusions this lack of observed efficacy of the REACH-

HF intervention increasing physical activity in HF. However, there are also several key issues in the intervention development research underpinning REACH-HF.

The REACH-HF intervention was developed using the Intervention Mapping Framework (IMF; Bartholomew et al., 2016). This thesis, which also follows the MRC guidelines, adopts alternative methods used in research informing intervention development, i.e. Theoretical Domains Framework (TDF; Cane et al., 2012) that will be described in this chapter. The use of TDF offers the following advantages over the IMF. The IMF, similarly to the TDF, prescribes a needs assessment that incorporates multiple perspectives (community, key stakeholders, healthcare professionals, and existing research) to gather evidence on the health behaviour in question and to identify potential barriers and enablers. However, the IMF takes an open-ended, less defined approach to the gathering of the evidence concerning barriers and enablers. While the TDF offers means to systematise and structure the research enquiry (Atkins et al., 2017). The TDF has been developed on the basis of a systematic review of existing behaviour change theories (Davies et al., 2012). Thus it includes a comprehensive set of domains that are potentially relevant to behaviour change. A qualitative study suggests that the employment of the TDF results in the identification of a broader range of the relevant barriers and enablers than using a single model/theory or no theory at all (Francis et al., 2009). REACH-HF drew on the expertise of stakeholders (such as cardiologists and nurses). This involved adopting a bottom-up stakeholder-oriented approach, where content analysis was not guided by a framework. In this thesis, the TDF was applied explicitly to structure the systematic review of barriers and enablers and the qualitative study's interview and content analysis.

Second, in contrast to REACH-HF, the present thesis explicitly focuses on one specific behaviour: *physical activity*. It has been previously indicated that focusing on a specific target behaviour is essential in providing a detailed account of how best to change it (Michie et al., 2013). A meta-analysis of behaviour change interventions also suggests that simultaneously addressing several behaviours is not beneficial in achieving a positive change in the target behaviour (Wilson et al., 2015). It is, therefore, recommended to explore how best to improve each behaviour while focusing on one behaviour at a time and subsequently design interventions that address one behaviour in detail.

Third, the present thesis evaluated the effects of a diverse set of interventions on the physical activity outcome. By contrast, the REACH-HF programme of research evaluated the efficacy of exercise-based rehabilitation on outcomes such as exercise capacity, hospitalisation, mortality and QoL in a meta-analysis. Also, the present thesis explored the content (BCTs, theory use), mode, setting and facilitator characteristics that contribute to increased efficacy in improving physical activity in HF.

Therefore, the present thesis provides a novel contribution to understanding how best to improve physical activity in HF by:

1. Focusing on this specific behaviour: physical activity.
2. Exploring what makes physical activity interventions efficacious in promoting an active lifestyle in a systematic review and meta-analysis.
3. Using TDF to guide systematic exploration of barriers and enablers to physical activity.

The aim of this thesis, therefore, is twofold: 1) to identify and evaluate reported interventions designed to increase physical activity levels in HF, and 2) to identify and describe barriers and enablers to physical activity in HF through systematic review and empirical research.

The present research does not include designing an intervention. Instead, it concentrates on the development stage as defined by the MRC guidance (Figure 3.1). It is intended that the findings of this research can help in informing the development of an evidence-based and theoretically underpinned intervention to increase physical activity in HF.

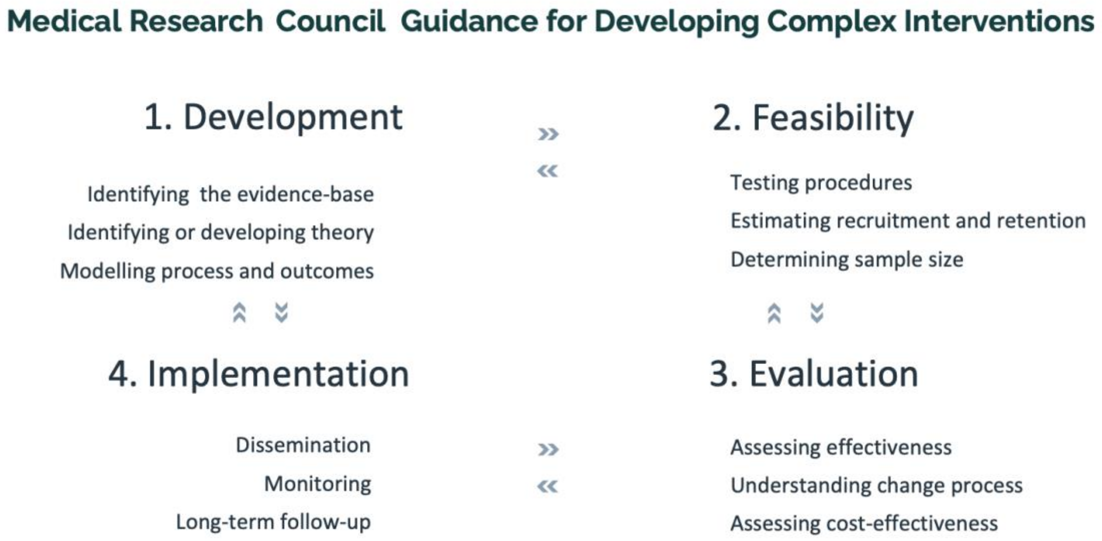

Figure 3.1. Key stages of the iterative process recommended for complex intervention development and evaluation (MRC guidance, 2008; 2019).

3.1 Identifying the evidence-base

The recommended practice for developing BCIs includes systematic evaluation of available evidence as the first step (Craig et al, 2008). Developing interventions that are not based on appropriate evidence and therefore are unlikely to be efficacious, is wasteful (O'Cathain, Croot, Duncan, et al., 2019). Systematic evaluation entails identifying what interventions work, for which subgroups of the population of interest, and in what setting. Thus, this study (i) evaluates existing physical activity interventions by performing a systematic review using meta-analysis (described in Chapter 4).

One limitation of systematic reviews evaluating BCIs stems from heterogeneity – systematic variance in the effects brought about by different study procedures, contexts, settings, and population samples, as well as the characteristics of BCIs. Such heterogeneity is inescapable due to the complexity of the subject – dynamic and complex human behaviour in dynamic and diverse environments in response to complex interventions. Some methods (Borenstein, Hedges, Higgins, & Rothstein, 2009), offer ways to explore heterogeneity by means of grouping and data representation. The MRC guidance suggests grouping BCIs in terms of modes of delivery, setting, duration, and frequency with which they are delivered (Craig et al., 2008). However, the coding of intervention content is often compromised by the flexibility in how complex BCIs can be described, grouped, and compared.

BCI content is extremely heterogeneous (Craig et al., 2008). It however can be specified in terms of Behaviour change techniques (BCTs) using BCT taxonomy v1 (Michie et al., 2013). This taxonomy will be used for describing BCIs in this thesis. BCT taxonomy v1 is expected to facilitate consistency in the description, grouping and comparison of the BCIs.

3.2 Identifying or developing appropriate theory

The MRC recommends identifying factors and the mechanisms that are likely to be important in bringing about behaviour change (Craig et al, 2008). Therefore, the study includes an investigation of barriers and enablers to physical activity through systematic review and a semi-structured interview study. This thesis draws upon psychological theories of behaviour change to help gain a better understanding of how to promote physical activity in people diagnosed with HF.

Theories of behaviour change summarise what is known about the mechanisms of behaviour change and the conditions in which behaviour change is most likely to occur (Michie & Johnston, 2012). Theoretical construct is defined as a component of a theory, which refers to a factor that influences behaviour (Michie et al., 2005). For example, self-efficacy is a theoretical construct – defined as one’s belief in one's ability to succeed in specific situations or accomplish a task, and is a component of a behaviour change theory, entitled Social Cognitive Theory (Bandura, 1997).

There are several challenges in using psychological theories for developing interventions. (Michie & Prestwich, 2010; Michie et al., 2011; Ogden, 2004). For one, the number of potentially applicable theories is large (Johnston & Dixon, 2008). Therefore, it is unclear which theory is most relevant to physical activity in HF. The potential success of a theory is contingent to the context in which the theory is applied (Moore & Evans, 2017). While it is important to have a broad range of perspectives in mind when considering what theory should be used, it is also important to justify the choice of theory (Moore & Evans, 2017). MRC guidance recommends justifying the choice by identifying what are the determinants of the behaviour through review and empirical research. In this thesis, Theoretical Domains Framework (TDF, Cane et al., 2012) is applied to structure both the systematic review process and empirical research.

Theoretical Domains Framework (TDF, Cane et al., 2012) is a tool developed through international collaborative effort. It systematically describes domains and constructs which influence a behaviour under investigation (Atkins et al. 2017). TDF summarises constructs of existing behaviour change theories into 14 domains, such as *Knowledge*, *Skills*, *Social/Professional Role* and *Identity*, *Beliefs about Capabilities*, *Optimism*, *Beliefs about Consequences*, *Reinforcement*, *Intentions*, *Goals*; *Memory*, *Attention and Decision Processes*; *Environmental Context and Resources*; *Social influences*; *Emotion*; and *Behavioural Regulation*. Domains are defined in Table 3.1 . TDF has been widely used in research (Atkins et al., 2017), including research on self-management in chronic conditions (Mulligan et al., 2017; McBain et al., 2017) and physical activity in healthy adults (McDonald et al., 2015; Taylor et al., 2013), as well as systematic review synthesis (Richardson et al., 2019). In this thesis, barriers and enablers to physical activity in HF identified through review and empirical research are categorised in accordance with TDF. The methods are described in Chapter 5 and 6, respectively.

Table 3.1. Theoretical Domains Framework definitions.

1. Knowledge	An awareness of the existence of something

2. *Social Influences*	An ability or proficiency acquired through practice
3. *Social/Professional Role and Identity*	A coherent set of behaviours and displayed personal qualities of an individual in a social or work setting
4. *Beliefs about Capabilities*	Acceptance of the truth, reality, or validity about an ability, talent, or facility that a person can put to constructive use
5. *Optimism*	The confidence that things will happen for the best or that desired goals will be attained
6. *Beliefs about Consequence*	Acceptance of the truth, reality, or validity about outcomes of a behaviour in a given situation
7. *Reinforcement*	Increasing the probability of a response by arranging a dependent relationship, or contingency, between the response and a given stimulus
8. *Intention*	Stability of intentions A conscious decision to perform a behaviour or a resolve to act in a certain way
9. *Goal*	Mental representations of outcomes or end states that an individual wants to achieve

10. Memory, Attention and Decision Processes Memory	The ability to retain information, focus selectively on aspects of the environment and choose between two or more alternatives
11. Environmental Context and Resources	Environmental stressors Any circumstance of a person's situation or environment that discourages or encourages the development of skills and abilities, independence, social competence, and adaptive behaviour
12. Social influences	Those interpersonal processes that can cause individuals to change their thoughts, feelings, or behaviours
13. Emotion	A complex reaction pattern, involving experiential, behavioural, and physiological elements, by which the individual attempts to deal with a personally significant matter or event
14. Behavioural Regulation	Anything aimed at managing or changing objectively observed or measured actions

Note: Adapted from the American Psychological Associations' Dictionary of Psychology (VandenBos, 2007); adapted from Cane et al., 2012.

A systematic review is performed to identify and describe barriers and enablers to physical activity in HF. Drawing conclusions from the evidence provided by systematic reviews investigating factors influencing a behaviour is not straightforward. The evidence often includes findings from both qualitative and quantitative studies. While quantitative research often includes only measurable outcomes and predictors, qualitative research provides detailed and broad accounts of factors (Dixon-Woods recommendation on reviews). Therefore, omitting qualitative research may result in a narrower set of identified barriers and enablers (Roberts et al., 2002). Dixon-Woods and colleagues suggest integrating all available evidence in informing decision making in healthcare (Dixon-Woods, Agarwal, Jones, Young, & Sutton, 2005). Following their prescription, to better understand how to increase physical activity in HF, qualitative and quantitative research findings will be systematically reviewed.

To integrate available evidence from diverse sources Dixon-Woods et al. (2006) recommend performing a Bayesian meta-analysis (Dixon-Woods et al., 2005, 2006; Roberts, Dixon-Woods, Fitzpatrick, Abrams, & Jones, 2002). In healthcare research, this has been previously carried out in a Bayesian evidence synthesis of the factors influencing immunisation uptake (Roberts et al., 2002). The beliefs that are elicited from qualitative evidence can be updated with quantitative evidence using Bayesian updating. Bayesian updating is defined as a procedure of updating prior belief by incorporating new information (Spiegelhalter et al., 2003). In the context of a meta-analysis, this technique is used to update a hypothesis once new evidence is available. 2002). It also makes it possible for a researcher to assess the degree of uncertainty. The rationale and methods are outlined in Chapter 5.

For physical activity in HF, a large fraction of the evidence is from qualitative research. There is also a large degree of uncertainty since physical activity is a complex behaviour. Bayesian meta-analysis is especially useful for integrating evidence in such cases. In Chapter 5, this framework is applied in synthesising available evidence regarding barriers and enablers to physical activity in HF.

This study also develops a detailed understanding of the perceived barriers and enablers identified using semi-structured interviews. Then the qualitative findings are used to identify constructs and theoretical domains, and the most relevant theory as indicated by the perceived causal relationships between them. Finally drawing on the evidence form the Bayesian review, meta-analysis, and the qualitative study a model explaining barriers and enablers in physical activity is formally defined using methods developed by Pearl (2009).

The latter can inform a large cross-sectional study designed to assess the proposed understanding of the barriers and enablers in a large study.

3.1 Conclusion

The series of studies presented here undertake an exploration of the barriers and enablers to engaging in physical activity among people with HF. The MRC guidance procedure is followed. Specifically, this thesis (1) evaluates the efficacy of existing physical activity interventions for people with HF. It then (2) synthesises in a systematic review and Bayesian meta-analysis the available evidence in support of barriers and enablers to physical activity in HF. (3) Using empirical research, it explores the barriers and enablers to physical activity in HF, as well as the casual structure that describes relationships among them. The thesis then (4) identifies appropriate theory and formulates detailed hypothesis to be tested in a large cross-sectional study.

4 Efficacy of Interventions to Increase Physical Activity for People with HF: A Systematic Review and Meta-Analysis of Randomised Controlled Trials

4.1 Background and rationale for systematic review methodology

Currently, despite the firm recommendation for medically stable individuals diagnosed with heart failure (HF) to engage in regular physical activity[3], its levels are very low worldwide (Jaarsma et al., 2013). However, physical activity is an important treatment strategy. Substantial research has been conducted on the effect of exercise programmes on health-related quality of life (HRQoL), hospitalisation, and mortality in HF. As reported in Chapter 2, exercise-based programmes improved exercise capacity (Davies et al., 2010; Lewinter et al., 2015; Taylor et al., 2014) and HRQoL (Davies et al., 2010; Taylor et al., 2014), and reduced hospitalisation (Davies et al., 2010; Lewinter et al., 2015; Taylor et al., 2014) in HF. Systematic reviews have indicated a trend towards improved survival in trials with a follow-up longer than 12 months (Sagar et al., 2015).

However, a recent meta-analysis did not suggest that CR is effective in sustaining physical activity in HF after it has ceased (Dibben et al., 2018). Besides, the uptake of CR remains suboptimal (Santiago de Araújo Pio, Chaves, Davies, Taylor, & Grace, 2019). It is, therefore, essential to evaluate the efficacy of a range of other interventions and identify

[3] The definition of physical activity is provided in section 2.13-2.14. The rationale for focusing on this behaviour is provided in section 2.12.

content and features of interventions that are likely to promote a physically active lifestyle and supplement CR.

On the other hand, CR is multifaceted. It may incorporate not only exercise but also components such as medical and lifestyle risk factor management, medication management, psychosocial health assessment, health behaviour change and education (Doherty & Harrison, 2017). Physical activity interventions, in common with any behaviour change intervention, are also complex and include many components aimed at improving the behaviour (Craig et al., 2008). An editorial (Clark, Redfern, & Briffa, 2014) highlighted that reviews of CR had not separated the effects of these different components. Also, an overview of Cochrane systematic reviews recommended that future reviews should explore the interventions ' complexity and identify what makes an intervention successful (Anderson & Taylor, 2014). This thesis is concerned with what makes any intervention successful in promoting physical activity.

A narrative review by Barbour & Miller (2008) identified only eight trials that measured physical activity in HF and concluded that the issue of its low levels in HF has been under-investigated. The review identified a lack of uniformity across trials in physical activity assessment and poor reporting of intervention procedures. The review concluded that long-term (beyond 12 months) strategies to enhance physical activity in HF have not been investigated. However, to achieve long-term benefits, an individual with HF would need to maintain an active lifestyle, which would involve a long-term performance of physical activity in everyday settings outside exercise programmes. Barbour & Miller (2008) therefore highlight the need to evaluate the efficacy of cardiac rehabilitation, exercise programmes, or other interventions that aim to promote the initiation and maintenance of physical activity behaviour outside an exercise programme.

Tierney et al (2012) extended previous research by focusing on controlled trials, assessing the effectiveness of interventions in improving physical activity behaviour. The review included nine controlled trials examining the efficacy of the strategies used to improve physical activity among people with HF. The authors found that multicomponent interventions were effective in the short-term, but the effects were not maintained 5 months after the intervention completion (Tierney et al., 2012). This narrative review suggested short-term effects were associated with strategies such as goal setting, feedback and problem solving, as well as with the use of a behaviour change theory (Tierney et al., 2012). Tierney et al. (2012) highlighted several limitations of the evaluated trials, including small and unrepresentative participant samples and poorly defined interventions, as well as a lack of follow-up assessment and objective measures of physical activity. The present chapter extends this line of research on methods to increase physical activity in HF and investigates the heterogeneity of both – content and type of physical activity interventions – in order to pinpoint efficacious intervention characteristics.

This chapter further contributes to the body of knowledge by identifying, annotating, and classifying the characteristics of Behaviour Change Interventions (BCIs; Chapter 3). BCIs can be described in terms of their general approach, behaviour change techniques (BCTs; Michie et al., 2013), settings, facilitator, delivery mode, duration and theory use. The clear, consistent, and systematic description of the interventions will then facilitate the reliable grouping and comparative analysis of efficacy associated with each identified characteristic (Michie & Johnston, 2017). This helps answer questions like: What (i.e. what BCTs, for whom, where) works in what combinations? What works better than the rest?

4.2 Aim

The aim of this review was to identify the evidence base regarding existing physical activity interventions for individuals with HF.

4.3 Objectives

- To carry out a systematic search of existing interventions designed *to promote physical activity in everyday life*;
- To evaluate the efficacy of the identified interventions in promoting everyday physical activity among individuals with HF *upon their completion*;

- To evaluate the *long-term efficacy* of the identified interventions in promoting everyday physical activity among individuals with HF;
- To identify the *characteristics* that are associated with efficacy in increasing everyday physical activity in HF.

4.4 Research questions

- Are existing interventions efficacious in increasing everyday physical activity in individuals with HF?
- What intervention characteristics contribute to the efficacy in increasing physical activity?

4.5 Methods

The review protocol is registered on the PROSPERO database (CRD42015015280). The authors of the included trials were contacted with a query about other existing trials.

4.5.1 Scope of the review and inclusion criteria

The scope of this review as well as its justification are outlined in this section and presented in the PICOT (Population – Intervention – Comparator treatment – Outcome of interest – Type of the study/Study Design) format for defining the research question and the study inclusion criteria.

4.5.1.1 Population of interest

The review included trials with adults diagnosed with HF. Literature concerning healthy adults or people with other chronic conditions was not included in the review.

4.5.1.2 Intervention of interest

All types of interventions aimed at increasing physical activity in HF (e.g. CR, exercise programmes etc.) were considered.

4.5.1.3 Comparator treatment

The interventions were compared either to usual care or an active comparator treatment. The scope was extended to trials with an active comparator treatment for the following reasons. First, usual care often contains at least one or two active behaviour change interventions (i.e. education, clinical advice). Second, the wider scope increased the statistical power of the meta-analysis. This choice may introduce confounding. The possible influence of such confounding was explored in sensitivity analysis.

4.5.1.4 Outcome of interest

The primary outcome of the present review was physical activity (the definition of physical activity was provided 2.13. Physical activity levels as assessed at the end of intervention delivery period or later (within a month) were included in the present review and meta-analysis.

4.5.1.5 Study design

Randomised controlled trials (RCTs) were included in this review as they are the gold standard for producing the evidence on the efficacy of any treatment.

4.5.2 Reporting and methodological quality

4.5.2.1 Reporting

This review has been reported in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA; Liberati et al., 2009) guidelines. The guidelines comprise a 27-item checklist and a four-phase flow diagram (Liberati et al., 2009). Adherence to the PRISMA statement has been found to be associated with improved methodological quality and improved quality of reporting of reviews (Panic, Leoncini, De Belvis, Ricciardi, & Boccia, 2013), which increases the confidence of the review in producing unbiased findings (Moher et al., 1995).

4.5.2.2 Quality assessment of this review

To assess the quality of the review A MeaSurement Tool to Assess systematic Reviews (AMSTAR 2) was utilised and is included in Appendix B. The AMSTAR 2 checklist comprises 11 items related directly to the necessary steps taken in order to reduce a risk of bias that can be introduced at different stages of the systematic review (Shea et al., 2017).

4.5.3 Data sources and searches

Cochrane Library, MEDLINE, CINAHL, EMBASE, AMED, HEED, PsychARTICLES, PsychINFO, and Global Health were screened from inception to April 2015. The search utilised English language key words, MeSH terms, and Boolean logical operators. HF-related synonyms were combined with ‘physical activity’-related synonyms. The synonyms were combined into domains using Boolean operator ‘OR’ and the domains were combined using operator ‘AND’ (the full search strategy is provided in Appendix C).

Web of Science and SCOPUS databases were searched for further citations. Electronic searches were supplemented with hand searching reference lists of relevant trials and contacting of the included trials.

Conference proceedings were accessed through ‘Web of Science: ISA Proceedings’, BIOSIS Preview, Index to Scientific and Technical Proceedings, ZETOC, and Conference Papers Index. Unpublished trials were searched on York Centre for Reviews and Dissemination databases and BASE Open Grey.

The following websites were also searched for relevant registered trials: Current Controlled Trials, ClinicalTrials.gov, The WHO International Clinical Registry Platform (ICTRP), UK Clinical Trials Gateway, and UK Clinical Research Network Study Portfolio.

The reviewers subscribed to email alerts from European Journal of HF, BMJ Journals and Willey Library, and to EBSCOhost and OVID alerts of the saved searches.

4.5.4 Study selection

Two reviewers, including the author of the thesis, independently assessed all titles and abstracts against the predefined inclusion criteria. Another reviewer screened titles and abstracts on which there was a disagreement to help reach consensus. Subsequently, full-text articles were independently examined by the two reviewers and the third reviewer resolved disagreements.

4.5.5 Data extraction

Data was extracted using a standardised data extraction form adapted from the form produced by the Cochrane Collaboration (Higgins, 2011a). Standardised data extraction forms can provide consistency in data extraction, while reducing bias and improving validity and reliability (Higgins, 2011).

The detailed descriptions of the outcome of interest were extracted. This included the definition of physical activity used by the authors, the details about its mode (e.g. walking, daily activity), type (e.g. aerobic), and intensity (e.g. MVPA), and the assessment method used.

4.5.6 Risk of bias assessment

The intrinsic validity of each individual study, as well as how it might have affected the overall results, was evaluated as recommended by the Cochrane Collaboration (1972).

The Cochrane Collaboration Risk of Bias tool (Higgins et al., 2011a)[4] was used to assess the methodological quality of the included trials. This tool is designed to monitor the biases that may have been introduced into trials. These biases included: *selection bias, performance bias, detection bias, attrition bias, outcome reporting bias*. Definitions are provided in Appendix D.

4.5.7 Data coding

To enable evaluation of the association between efficacy of the interventions in promoting physical activity and the characteristics of the interventions, the interventions were coded in terms of their characteristics, as described below.

4.5.7.1 Use of behaviour change theory

The use of behaviour change theory was assessed from study reports. In the context of behaviour change, a theory seeks to describe why, when and how a behaviour does or does not occur (Michie et al., 2014). A theory can be used to inform intervention. To describe the extent to which a theory of behaviour change was used in designing the interventions, the Theory Coding Scheme (TCS) (Michie & Prestwich, 2010) was utilised. The TCS provides a score ranging from zero (no theory) to eight (most extensive theory use).

4.5.7.2 Intervention content

Interventions that are different from one another should be evaluated separately (Borenstein et al., 2009). Therefore, interventions were categorised in terms of general approach, setting, mode of delivery, and constituting strategies. This grouping ensures that interventions being evaluated in a meta-analysis are equivalent.

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[4] Risk of bias tool 2 (Sterne et al., 2019) was used on the entire set of identified studies, after updated literature search performed in January 2020. The results are reported in the appendices

4.5.7.3 General approach

Interventions that aim to increase physical activity vary in their approach. They range from education programmes, which only include advice to exercise, to more complex programmes incorporating exercise practice sessions and behaviour change. These broad differences in content across the identified interventions are referred to as 'general approach'.

4.5.7.4 Behaviour change techniques

Interventions that aim to change behaviour typically incorporate a variety of different strategies, or 'behaviour change techniques' (BCTs) to do so. BCTs are defined as the active ingredients of a behaviour change intervention (Michie et al., 2013). To identify whether BCTs appear to be key to bringing about change in physical activity, we coded the BCTs that were included in each intervention, using a standardised taxonomy, the BCTTv1, described in Chapter 3. Using the BCTTv1 enables the researcher to classify interventions in terms of their content, making sure that interventions being grouped for a meta-analysis are equivalent in their content. Thus, employing the BCTTv1 enhances replicability, evaluation and synthesis of evidence in the present meta-analysis.

The author of the thesis, who is trained in using the BCTTv1 Taxonomy, coded the content of all interventions. To increase coding reliability, intervention content was also independently coded by another experienced coder who is also trained in using the BCTTv1 Taxonomy. Disagreements were resolved through discussion. Each of the BCTs had to be present in at least two interventions to be included in the analysis. For example, to evaluate the efficacy of goal setting, the goal setting had to be present in at least two interventions to provide enough variance in efficacy for carrying out the analysis.

4.5.7.5 Intervention setting

In this review, interventions were classified according to where they were delivered, i.e. home-based interventions and centre-based interventions. Home-based interventions were those in which the intervention took place at the participant's home. The home-based interventions were delivered via home visits, letters or telephone calls from staff, self-monitoring diaries, or telehealth device. Centre-based interventions refer to interventions that were delivered in a variety of settings outside the participant's home (e.g. outpatient clinics, and community centres).

4.5.7.6 Mode of delivery

The mode of delivery refers to how the intervention was delivered (i.e.; Website; telemonitoring; DVD; group; individual). Facilitator was defined as the individual(s) who delivered the intervention, for example, nurse, physiotherapist. Contact time was defined as total time of intervention (in minutes or hours), calculated as the number of sessions multiplied by the duration of each session.

4.5.8 Statistical analysis

Meta-analysis was performed to evaluate the efficacy of the identified interventions. Meta-analysis is the preferred method of review when evaluating treatment efficacy (Sutton, Abrams, et al., 2000). Firstly, a meta-analysis includes more participants than any one of its constituent studies, has more statistical power, and reduces the effect of random error. Thus, it produces more reliable estimates of effect than any individual study (Maynard & Chalmers, 1997; Peto, 1987). Secondly, a meta-analysis enables the exploration of variation in efficacy and the association between this variation and the presence of particular intervention characteristics (Thompson, 1994).

4.5.8.1 Overall efficacy

It was planned to examine the interventions' immediate physical activity effects as well as long-term efficacy. **Post-completion efficacy** is defined as the effect of an intervention measured either at completion or up to one month after the intervention ended **Long-term efficacy** is defined as efficacy measured after the intervention completion (up to 3 months after the end of intervention; up to 6 months after the end of intervention; and 12-month after the end of intervention).

4.5.8.2 Summary statistic

Standardised mean differences (*SMD*) were calculated for all between-group comparisons for each study to estimate the effect size of an intervention. Meta-analysis using a random effect model was performed to evaluate the overall efficacy of interventions using Comprehensive Meta-Analysis software[5] (Borenstein, Hedges, Higgins, & Rothstein, 2005). Since clinical and methodological diversity is common for all trials, in a meta-analysis, statistical heterogeneity is inevitable (Borenstein et al., 2009; Higgins, 2013). Thus, the use of random model meta-analysis is recommended.

4.5.8.3 Heterogeneity

A Q-statistic was used to assess the presence of between-study heterogeneity. Heterogeneity index (I^2) is reported as the total unexplained variability in effect. τ^2 and τ are reported as the dispersion and standard deviation of the true underlying effect, respectively. Efficacy at intervention completion, 3-month, 6-month (short-term), and 12-month (long-term) follow-up was evaluated.

I^2 is the percentage of the variability in effect estimates that is due to heterogeneity rather than chance. I^2 results were interpreted as recommended by Higgins et al. (2011b) as follows. If the value of I^2 is between 0% and 40% the inconsistency might not be important; if between 30% and 60%, there is moderate heterogeneity; 50% and 90% substantial heterogeneity; 75% and 100%: considerable heterogeneity. As recommended by Higgins et al. (2011), I^2 was interpreted with caution because its value depends on (i) the magnitude and direction of effects and (ii) the strength of evidence for heterogeneity (e.g. p-value from the chi-squared test, or a confidence interval for I^2).

[5] `Metafor` in **R** was used for the updated meta-analysis (appendices A). To exclude a potential bias stemming from the use of new methods, the meta-analysis of the original search was also reproduced using new software. This procedure follows a recommendation of the Cochrane Collaboration (Higgins et al., 2011). The trials that were identified in the original search (2015) were evaluated in metafor and no differences with the results suggested by the meta-analysis carried out in the Comprehensive Meta-analysis software were identified.

Some heterogeneity is spurious but other heterogeneity is meaningful. The causes of the latter include differences in efficacy arising from intervention characteristics and sample differences. Investigating these causes is the goal of exploratory meta-analysis.

4.5.8.4 Exploratory meta-analysis

The association between efficacy and intervention characteristics was assessed. Exploratory meta-analysis was performed by means of subgroup analysis and meta-regression. Subgroup analysis systematically groups interventions, based on identified differences in categorical variables, and compares the efficacy of these groups. Meta-regression is used in meta-analysis to examine the impact of continuous moderator variables on efficacy using regression-based techniques. Moderator variables in this meta-analysis are as follows: theory use, contact time and participants characteristics.

An exploratory meta-analysis may lead to clinically important findings and may subsequently assist in refining interventions (Gelber & Goldhirsch, 1987). It helps to explore the complexity of behaviour change interventions, by identifying intervention characteristics that differentiate between efficacious and non-efficacious interventions. It informs about differences in efficacy among subgroups of participants, which helps in identifying the target population most in need of intervention.

4.5.8.4.1 Subgroup analysis

The included trials were grouped by intervention content (both general approach and BCTs), setting, mode of delivery, and facilitator. Trials were dummy coded on each of these variables as follows: present = 1 and not present = 0. Pairwise Z-tests for these categorical variables were performed to test for differences between subgroups of trials with and without each intervention characteristic (Borenstein et al., 2009). Each characteristic had to be present in at least two interventions to be included in the subgroup analysis.

4.5.8.4.2 Meta-regression analysis

Multiple meta-regression analyses implemented by the maximum likelihood method were used to evaluate the association between physical activity effect size and the following: TCS score (theory use), contact time, sample mean age, left ventricular ejection fraction (LVEF), proportion of males, and proportion of study sample characterised as NYHA class II-III. The present meta-analysis included a small number of trials and many potential moderators. The use of meta-regression with multiple covariates is not a recommended option when the number of trials is small (Borenstein et al., 2009). Therefore, each moderator (i.e. contact time; theory use; number of BCTs) was assessed separately, as recommended by Borenstein et al. (2009).

4.5.8.5 Sensitivity analysis

Sensitivity analysis was performed. A sensitivity analysis is a replication of the primary meta-analysis with substitution of decisions that were arbitrary or unclear (Higgins & Green, 2011). Sensitivity analysis determines whether the findings are robust to the decisions that were made during the process of obtaining them. When some trials were considered to introduce a bias in the meta-analysis, sensitivity analysis involved undertaking the meta-analysis twice: first, including all trials and second, only including trials that are known to not introduce the bias. The results are compared and the judgement about whether bias has influenced the findings is made (Higgins & Green, 2011).

4.5.9 Publication bias assessment

Publication bias may occur in reviews because trials with significant results are more likely to be submitted, published, or published more rapidly (Song et al., 2009). Therefore, to produce a balanced review a screening of unpublished work is recommended (Higgins et al., 2011). This was done by including grey sources of literature. In addition, publication bias was evaluated using funnel plot evaluation (Egger, Smith, Schneider, & Minder, 1997) & Trim and Fill (Duval & Tweedie, 2000).

To detect publication bias, an informal examination of a funnel plot was performed. A funnel plot shows effect sizes observed by studies as a function of their precision. Precision was measured by standard error (SE) (Sterne, Egger, & Smith, 2001). The method is currently recommended for use in meta-analysis of continuous outcomes if the number of trials exceeds ten (Higgins & Green, 2011). Trim and Fill test was planned to be performed to reflect on the implications of the publication bias and for the evaluation of the validity of the results of the systematic review and meta-analysis.

4.6 Results

4.6.1 Results of the search

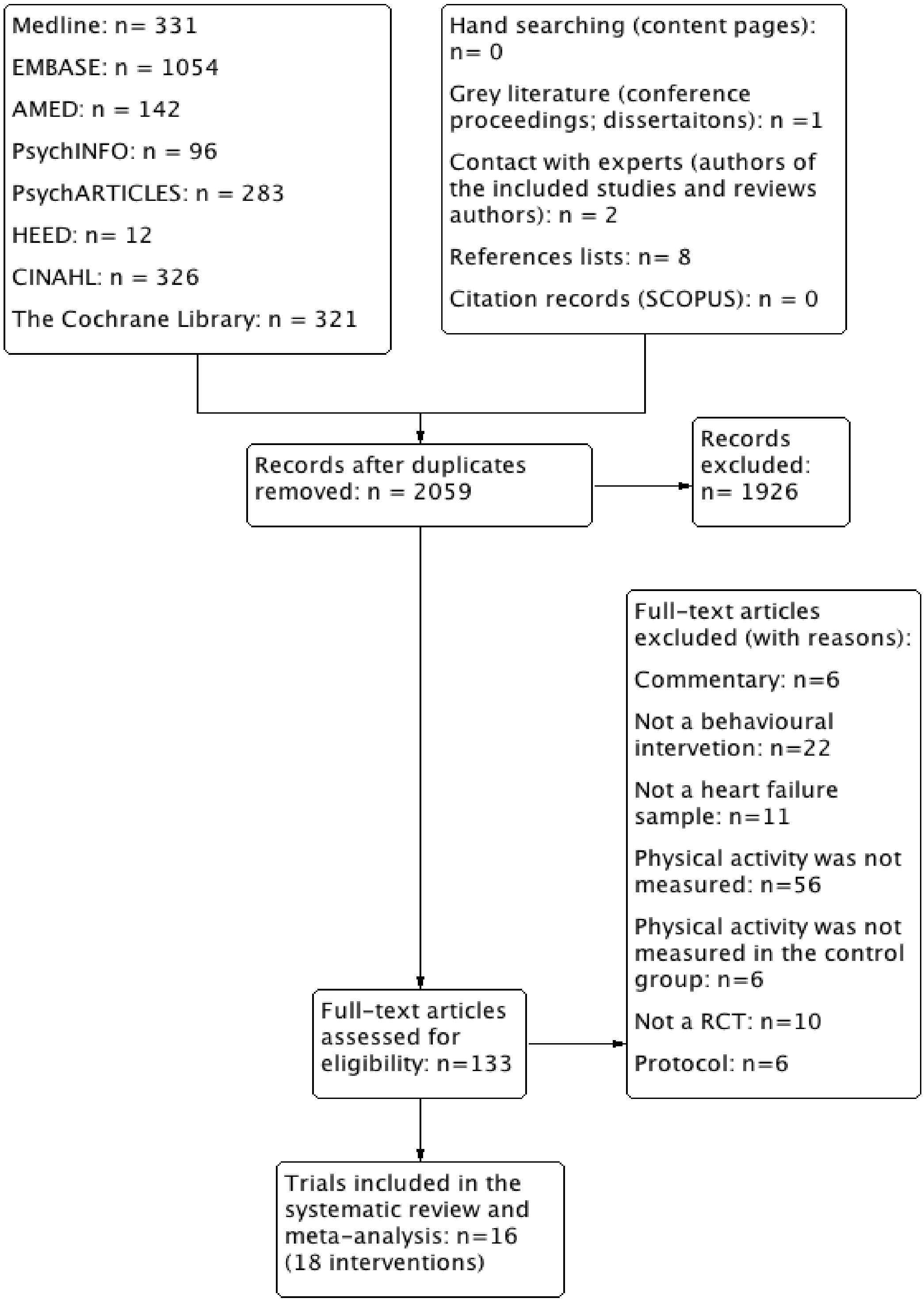

Figure 4.1. Review flow diagram.

The search results and reasons for exclusion are listed in the PRISMA diagram illustrated in Figure 4.1 (Moher, Liberati, Tetzlaff, & Altman, 2009). A total of 2059 records were identified, 133 were screened in full text. Many screened trials (n=56) satisfied the first two criteria for inclusion but did not report the levels of physical activity as the study outcome and therefore could not be included in the review.

4.6.2 Study characteristics

After screening, 16 trials evaluating 18 interventions remained (Barnason et al., 2003; Boyne et al., 2014; Brodie & Inoue, 2005; Collins et al., 2004; Corvera-Tindel, Doering, Gomez, & Dracup, 2004; Cowie, Thow, Granat, & Mitchell, 2011; Duncan & Pozehl, 2003; Jolly et al., 2009; O'Connor et al., 2009; Smeulders et al., 2009; Tomita et al., 2008; van den Berg-Emons, Balk, Bussmann, & Stam, 2004; Willenheimer, Erhardt, Cline, Rydberg, & Israelsson, 1998; Witham et al., 2005; Yeh et al., 2011).

The identified trials were published in the period from 1999 to 2014. Seven were conducted in Europe, six in the USA, and one in both Europe and USA. The characteristics of the included trials are described in Table 4.1 . This meta-analysis includes 4073 participants in total. The median sample size was 62 participants. Over half of the included sample (*N*=2331; 57%) is drawn from one trial – HF-ACTION (O'Connor et al., 2009).

Table 4.1. The characteristics of the included trials and participants.

Author, year	Country	*N* (control)	*N* (intervention)	Follow-up (since intervention ended)	Mean age	Male, %	LVEF, %	Proportion of participants (%) in NYHA II and NYHA III
Barnason et al., 2003	USA	17	18	3 months	74	72	<40	Not reported
Berg-Emons et al., 2004	Netherlands	16	18	None	59	81	24	56; 44
Boyne et al., 2014	Netherlands	185	197	None	71	58	<40	29; 21
Brodie et al., 2005; 2008	UK	32	30; 30	None	79	Not reported	30	28; 58
Collins et al., 2004	UK	16	15	None	64	100	29	Not reported
Corvera-Tindel et al., 2004a	USA	42	37	None	62.6	99	27	80; 20
Cowie et al., 2013	UK	20	20; 20	None	66	85	<40	62; 38
Duncan et al., 2003	USA	6	7	3 months	66	Not reported	30	Not reported
O'Connor et al., 2009 (HF-ACTION)	USA (88.72%); Canada (8.07%); France (3.33%	1172	1159	12; 30 months	59	72	<35	62; 36
Jolly et al., 2009, 2007	UK	85	84	None	66	76	<40	75; 20
Koelling et al., 2005	USA	116	107	None	65	58	26	Not reported
Smeulders et al., 2009	Netherlands	131	186	6; 12 months	67	73	<40	64; 36
Tomita et al., 2008	USA	13	19	None	76	32.5	Not reported	79; 21
Willenheimer et al., 1998	Sweden	27	23	6 months	64	70	35	50; 36
Witham et al., 2005	UK	41	41	6 months	80	63	Not reported	61; 39
Yeh et al., 2004	USA	50	50	None	68	56	29	62; 18
Overall		**2022**	**2051**		**67.8 (SD=6.24)**	**72.1 (SD=17.46)**	**29 (SD=4.24)**	**NYHA class II: 59 (SD=16.80)**

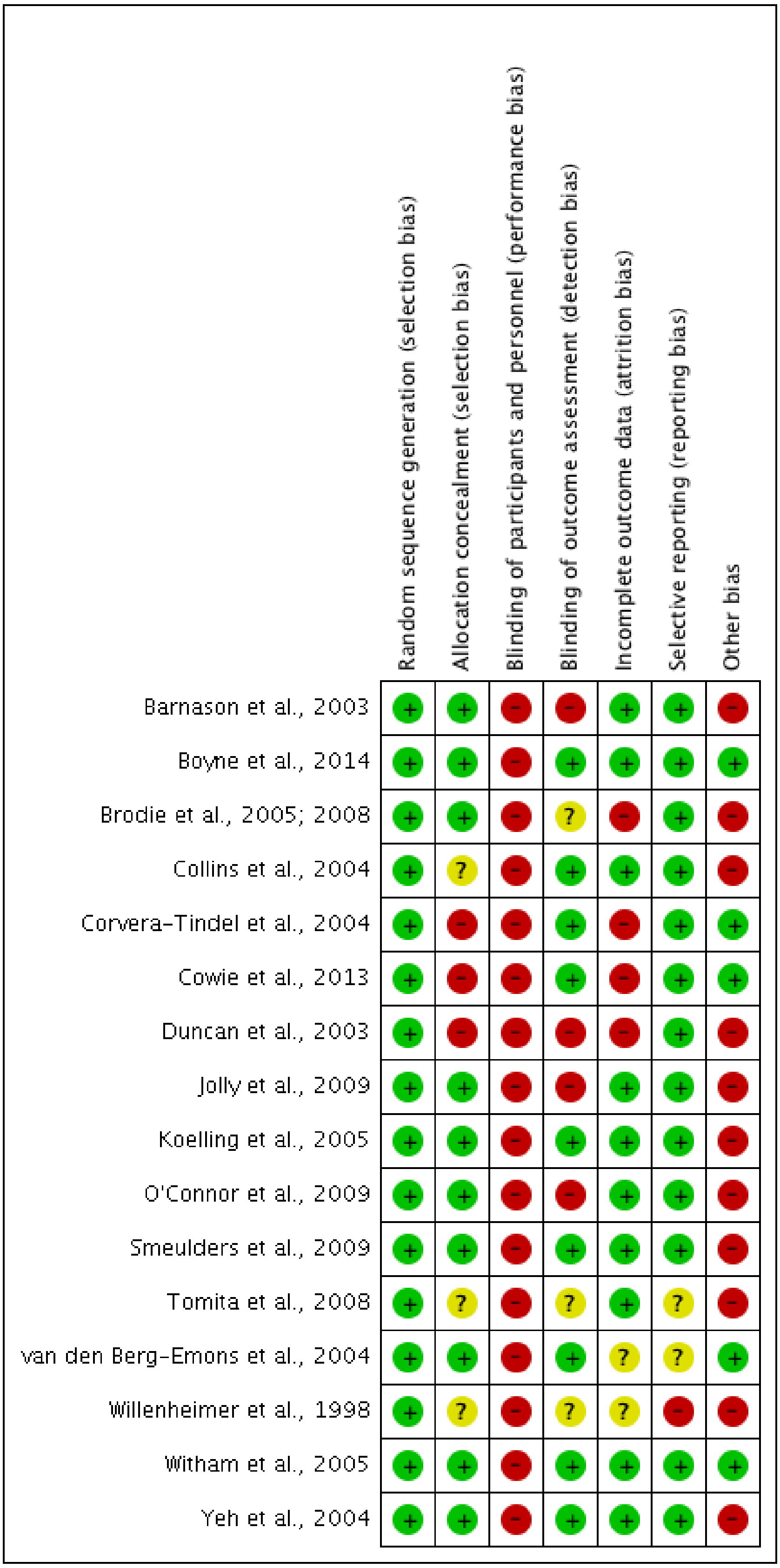

Figure 4.2. Risk of bias summary illustrating the judgement about each risk of bias item for each included study (Higgins et al., 2011a); produced in RevMan v5.3.

4.6.3 Risk of bias

The risk of bias across trials was moderate. The sources of biases are summarised in Figure 4.2. Participant blinding was not possible. One of the other frequent biases included the use of self-reports in seven studies (Barnason, 2003; Boyne et al., 2014; Brodie & Inoue, 2005; Collins et al., 2004; Duncan & Pozehl, 2003; Jolly et al., 2007; Koelling et al., 2005; O'Connor et al., 2009; Smeulders et al., 2009; Tomita et al., 2008; Willenheimer et al., 1998; Yeh et al., 2011). The main intervention received a significantly greater dose of beta-blockers and ACE inhibitors than the control group in one study (Koelling et al., 2005). The outcome assessment was not blinded in four studies (Barnason, 2003; Duncan & Pozehl, 2003; Jolly et al., 2007; O'Connor et al., 2009). Attrition bias was present in four studies (Brodie & Inoue, 2005; Corvera-Tindel et al., 2004a; Cowie et al., 2011; Duncan & Pozehl, 2003). Allocation to either a main intervention or the control treatment was not concealed in three studies (Corvera-Tindel et al., 2004a; Cowie et al., 2011; Duncan & Pozehl, 2003). The graph of biases illustrating the percentage of studies prone to each of the biases is illustrated in Figure 4.3.

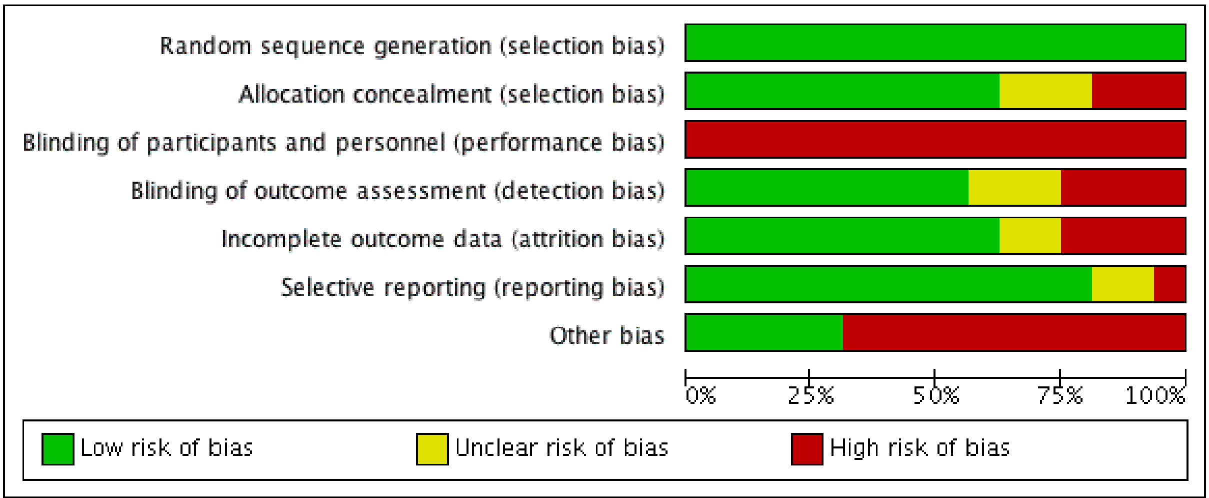

Figure 4.3. Risk of Bias Graph (Higgins et al., 2011a).

4.6.4 Participants characteristics

Participant characteristics are reported in Table 4.1. The trials included individuals diagnosed with HF with reduced ejection fraction, who were recruited from inpatient (N=854 (20.97%)) (Barnason, 2003; Berg-Emons et al., 2004; Brodie & Inoue, 2005; Collins et al., 2004; Koelling et al., 2005; Smeulders et al., 2009; Tomita et al., 2008; Willenheimer et al., 1998; Yeh et al., 2011) or outpatient (N=3219, 79.03%) services (Boyne et al., 2014; Corvera-Tindel et al., 2004a; Cowie et al., 2011; Duncan and Pozehl, 2003; O'Connor et al., 2009; Witham et al., 2005). Mean age of the samples varied from 59 (O'Connor et al., 2009) to 80 years old (Witham et al., 2005). The mean age of the total sample included in the meta-analysis was 67.8 (SD=6.24). Individuals younger than 70 years old were recruited in eleven out of 16 trials and constituted 82.2% of the total sample. Across trials, most of the samples were male (75.64%). Half of each trial sample comprised individuals with HF of ischaemic aetiology. Most participants were NYHA class II (52.97±17.83%) or III (38.81±17.77%), and had severely impaired left ventricular ejection fraction, *mean* LVEF (%) = 28.73 (*SD*=14.89). Diagnosis duration, comorbidities and exclusion criteria were not consistently reported.

4.6.4.1 General approach

Characteristics of the interventions are described in Appendix E. The identified general approaches include *Exercise*, *Exercise and Behaviour Change*, *Chronic Disease Self-management Programme*, *Motivational Interviewing*, *Remote Monitoring and Feedback*, and *Education*.

An intervention was categorised as an exercise programme if it included only exercise without an additional education, counselling, monitoring or other approach. Exercise programme is a well-established and stand-alone approach reported in the literature that aims to improve several health outcomes in HF (Chapter 2). Exercise programmes are referred to as *Exercise* and were evaluated in eight trials (Berg-Emons et al., 2004; Collins et al., 2004; Corvera-Tindel et al., 2004a; Cowie et al., 2011; Jolly et al., 2007; Willenheimer et al., 1998; Witham et al., 2005; Yeh et al., 2011).

A combination of a behaviour change intervention with an exercise programme (*Exercise and Behaviour Change*) is a second distinct approach. First, unlike exercise programmes, *Exercise and Behaviour Change* recognises a need to approach physical activity as a behavioural problem: an exercise programme might not be enough in bringing about change, and a change in psychological determinants is required. Second, *Exercise and Behaviour Change* is distinct in its content and may include qualitatively different behaviour change strategies than *exercise* (e.g. goal setting). Two trials evaluated *Exercise and Behaviour Change* (Duncan & Pozehl, 2003; O'Connor et al., 2009).

The *Chronic Disease Self-management Programme* approach was evaluated in one trial (Smeulder et al., 2009). It is a well-established intervention approach (Elzen, Slaets, Snijders, & Steverink, 2007; Johnston, Liddy, Mill, & Irving, 2012; Murphy, Saunders, Campbell, Jackson, & Berlowitz, 2003; Risendal et al., 2014; Tomioka, Braun, Compton, & Tanoue, 2012). The programme does not include supervised exercise sessions but aims to increase physical activity (as well as other self-management behaviours) by teaching problem solving and decision making to enhance self-efficacy in performing physical activity.

A fourth identified approach was *Motivational Interviewing* (Miller & Rose, 2009) – a clinical method in psychotherapy, which emphasizes patient-counsellor relationships and involves a number of one-to-one sessions where an individual is engaged by the therapist into the verbal reinforcement of his/her intention and motivation to change. Motivational interviewing was evaluated in two arms of one RCT (n=2) (Brodie & Inoue, 2005).

Another identified approach to increasing physical activity was remote disease-specific education with self-care support via monitoring and feedback. This approach was differentiated from the approaches above because it did not include: a supervised exercise programme, or counselling, or face-to-face teaching sessions on self-management. Instead, the programme provided remote, continuous and tailored information about HF disease as well as support of (a) health care professional(s). It also included intensive monitoring and feedback on physical activity as well as other self-management behaviours. This approach is referred to as *Remote Monitoring and Feedback* and was evaluated in three trials (Barnason et al., 2003; Boyne et al., 2014; Tomita et al., 2008).

Education was defined as (a) session(s) with a healthcare professional that includes discussion of HF–specific information, for example the causes of HF, rationale for pharmaceutical therapies followed by recommendations on lifestyle changes, including rationale for engaging in physical activity and the provision of information on current guidelines. It differs from the categories above in that it does not include an exercise session, counselling, monitoring and/or feedback, but provides an individual with explicit physical activity recommendations. *Education* was evaluated in one trial (Koelling et al., 2005).

4.6.4.2 Settings

Interventions were delivered in the following settings: Home-based (n=8) (Barnason, 2003; Boyne et al., 2014; Brodie & Inoue, 2005; Corvera-Tindel et al., 2004a; Cowie et al., 2011; Jolly et al., 2007; Tomita et al., 2008) and Centre-based (n=8) ((Berg-Emons et al., 2004; Collins et al., 2004; Cowie et al., 2011; Koelling et al., 2005; O'Connor et al., 2009; Smeulders et al., 2009a; Willenheimer et al., 1998; Yeh et al., 2011); and Both – home-based and centre-based (n=2) (Duncan & Pozehl, 2003; Witham et al., 2005).

4.6.4.3 Facilitator

Facilitators of the interventions were: A HF specialist nurse (n=4) (Boyne et al., 2014; Brodie & Inoue, 2005; Smeulders et al., 2009a); Physiotherapist (n=5) (Collins et al., 2004; Cowie et al., 2011; O'Connor et al., 2009; Willenheimer et al., 1998; Witham et al., 2005); Exercise instructor (n=3) ((Cowie et al., 2011; Jolly et al., 2007; Yeh et al., 2011); Nurse (speciality not specified) (n=3) ((Barnason, 2003; Corvera-Tindel et al., 2004a; Koelling et al., 2005); a multidisciplinary team (n=1) (Duncan & Pozehl, 2003).

4.6.4.4 Modes of delivery

1. In groups (n=8) (Berg-Emons et al., 2004; Collins et al., 2004; Duncan & Pozehl, 2003; O’Connor et al., 2009; Smeulders et al., 2009a; Willenheimer et al., 1998; Witham et al., 2005; Yeh et al., 2011);
2. Individually in person (n=6) ((Brodie & Inoue, 2005; Corvera-Tindel et al., 2004a; Cowie et al., 2011; Jolly et al., 2007; Koelling et al., 2005);
3. Using a telemonitoring device (n=2) (Barnason, 2003; Boyne et al., 2014), website (n=1) (Tomita et al., 2008); or a DVD (n=1) (Cowie et al., 2011).
4. The number of sessions varied from 364 sessions of remote monitoring and feedback intervention (Boyne et al., 2014) to one session of education (Koelling et al., 2005). Total contact time in minutes varied between 60 (Koelling et al., 2005) and 6000 (Collins et al., 2004). The median contact time was 930 minutes (IQR: 2565; 480).

4.6.4.5 Theory use

The definition of theory is provided in Chapter 3. Only seven out of 18 interventions were informed by a theory of behaviour change. The average TCS score (use of theory) was four (SD=2.39), and scores ranged from two (Brodie & Inoue, 2005; Tomita et al., 2008) to the maximum of eight (Smeulders et al., 2009). The included trials used the Social Cognitive Theory (Bandura, 1997) the Transtheoretical Model of Change (Prochaska & DiClemente, 1986) and Motivational interviewing (Miller & Rose, 2009) to inform intervention development There was some overlap in use of theories, in that an intervention was based on a combination of theories in two studies (O’Connor et al., 2009; Tomita et al., 2008). A description of the included theories is given below.

4.6.4.5.1 Social Cognitive Theory

Social Cognitive Theory (SCT) postulates that human behaviour, personal factors and environment are interrelated. It highlights the role of one’s capability to influence functioning as well as the environment by the means of one's own actions (Bandura, 2006). Bandura (1997;

2006) suggests that behaviour may be learnt vicariously, through observation and imitation (modelling), which is referred to as observational learning. SCT proposes four capabilities that drive human behaviour:

a. Intentionality – which refers to the capability to form an intention to act, as well as to the action plans and strategies used to realise the action (Bandura 1991).

b. Forethought – refers to the capability to set goals and to foresee outcomes of prospective actions (outcome expectancies) which guides and motivate one's efforts (Bandura, 2009a, p. 8).

c. Self-regulation – is the capability to regulate one's behaviour to respond to the discrepancies between the actual behaviour and the desired behaviour, based on one's standards and the demands of the environment. Self-regulation is governed by self-monitoring, self-guidance – evaluation of one's performance against personal standards, and self-reactions – actions directed at correcting one's performance (Bandura 1986, 1991).

d. Self-reflection – is a capability to make a judgement of one's ability to perform a behaviour referred to as perceived self-efficacy. Within SCT, self-efficacy is highlighted as the strongest predictor of thoughts, feelings, motivation and actions (Bandura, 1997).

Across the included trials, the interventions that mentioned SCT, focused on two elements of the theory – self-efficacy and intentionality. Duncan et al. (2003) targeted forethought by means of goal setting and intentionality by means of action planning. Barnason et al. (2003) and Smeulders et al. (2009) targeted self-efficacy by means of problem solving. However, other elements of SCT, such as outcome expectancies, self-regulation and observational learning were not addressed in the design of the interventions.

4.6.4.5.2 Transtheoretical Model of Change

The Transtheoretical Model of Change (TTMC; Prochaska & DiClemente, 1986) proposes that individuals transition through five stages before forming a habitual behaviour. These stages are pre-contemplation; contemplation; preparation; action and maintenance. At the pre-contemplating stage an individual is not considering engaging in behaviour. At the contemplating stage, an individual is considering advantages and disadvantages of engaging in behaviour, and may feel ambivalent towards the behaviour. At the preparation stage, an individual has formed an intention to engage in the behaviour and may have made several attempts. However, the behaviour is not yet stable and has not reached a health-promoting effect. At the action stage, and individual has invested effort to establish behaviour. The behaviour is stable enough to produce health benefits. The action stage is proposed to last for about 6 months. The maintenance stage involves an individual steadily engaging in behaviour over a prolonged period. For each of the stages the TTMC proposes several techniques that can assist an individual in transitioning from one stage to another. The TTMC formed the basis of the intervention evaluated in HF-ACTION trial (O'Connor et al., 2009). However, the trial report did not describe how the theory had been applied.

4.6.4.5.3 Motivational Interviewing

Motivational interviewing (Miller & Rose, 2009) was conceptualised as a theoretical approach in the reviewed studies. Motivational interviewing (MI) first emerged as a clinical method in psychotherapy (Miller, 1983). MI is often used to reduce risk behaviours and overcome an individual's resistance to change. MI aims to resolve ambiguity towards behaviour change and establish strong determination to change. Research exploring the underlying mechanism by which MI affects behaviour led to the formulation of a theory of MI (Miller & Rose, 2009). The theory was proposed to comprise two constructs: a relational construct – the importance of interpersonal relationships and empathy, and a technical construct – a process of reinforcing intention and motivation to change by means of self-talk (Miller & Rose, 2009). MI draws upon self-perception theory (Bem, 1967), formulation of cognitive dissonance (Festinger's et al., 1957) and the theory of conditions of therapeutic personality change (Rogers, 1957). MI provides a clear description of theoretical constructs as outlined above as well as the relationships among them and provides a suggestion on how the behaviour can be changed. Thus, MI responds to the definition of theory operationalised in this study (definition provided in Chapter 3, p 36). MI was used in the design of three of the included interventions, two of those reported in the three-arm trial by Brodie et al. (2008), and one in the HF-ACTION trial (O’Connor et al., 2009; Whellan et al., 2007).

4.6.5 Behaviour change techniques

Interventions were independently coded by two researchers. An agreement of 80% was reached (Kappa=0.36) which is thought to indicate fair agreement (Landis & Koch, 1977). Twenty BCTs aimed at changing physical activity were used in more than two interventions. Definitions are included in Appendix F. The average number of BCTs was 6.83 (*SD*=3.93) and varied from three (Barnason, 2003; Berg-Emons et al., 2004; Brodie & Inoue, 2005) to 16 (O’Connor et al., 2009).

4.6.6 Characteristics of control/comparator trial arms

Eleven interventions were compared to unspecified usual care (Barnason, 2003; Collins et al., 2004; Corvera-Tindel et al., 2004a; Cowie et al., 2011; Koelling et al., 2005; O’Connor et al., 2009; Smeulders et al., 2009; Tomita et al., 2008; Witham et al., 2005; Yeh et al., 2011). In other trials, the main interventions were evaluated against an active comparator group – *Exercise and Behaviour Change* was compared to aerobic exercise training (n=1) (Duncan & Pozehl, 2003), and motivational interviewing was compared to education delivered by a HF specialist nurse (n=1) (Brodie & Inoue, 2005), *Education* was compared to usual care without provision of the advice to exercise (n=1) (Berg-Emons et al., 2004), and *Exercise* was compared to usual care with discouragement to exercise (n=1) (Willenheimer et al., 1998). The comparator arms, on average, included 1.33 (SD=1.78) behaviour change techniques (BCTs).

4.6.7 Physical activity outcome assessment

The physical activity outcome was operationalised and assessed in a variety of ways (Appendix G). Four trials assessed *daily physical activity*. This was done using either accelerometers (Berg-Emons et al., 2004; Cowie et al., 2011; Witham et al., 2005) or self-report measures (Collins et al., 2004). Willenheimer et al. (2001) assessed *habitual physical* *activity* using a formula reported in Appendix G. *Walking* was the outcome in three trials. In one trial it was assessed using a pedometer (Corvera-Tindel et al., 2004a), and in two using self-reports (Smeulders et al., 2009; Tomita et al., 2008). Five trials assessed *exercise*, three of which conceptualised exercise as a part of self-care behaviours using a questionnaire (Barnason, 2003; Boyne et al., 2014; Koelling et al., 2005) and two studies assessed self-reported unspecified exercise (Duncan & Pozehl, 2003). The trials by Smeulders et al. (2009) and Tomita et al. (2008) presented multiple physical activity outcomes (walking, swimming, cycling, & 'other' and walking, breathing, stretching, & mild exercise, respectively) but did not report the total activity score. In these instances, the *walking* outcome was included in the meta-analysis because it is the most common physical activity mode in HF (González et al., 2004; Klompstra et al., 2015) and corresponds to the mode of physical activity assessed in other included trials.

4.6.8 Impact of interventions on physical activity levels

3.1.1.1 Post-completion

The primary outcome of this meta-analysis is everyday physical activity that takes place once intervention is ceased. Therefore, physical activity levels assessed at post-completion were included. Post-completion was defined as any time from the end of the intervention period up to one month after the end of the intervention period. A non-significant medium (*SMD*=0.58) effect was found, 95% *CI*:[-0.16; 1.34]. The overall effect and the individual study effects (95% *CI*) are illustrated in Figure 4.2. There was high variability between studies estimates indicated by the significant Q test value (Q=1249.53, df= 17, p<0.001) suggesting a considerable heterogeneity in the effects.

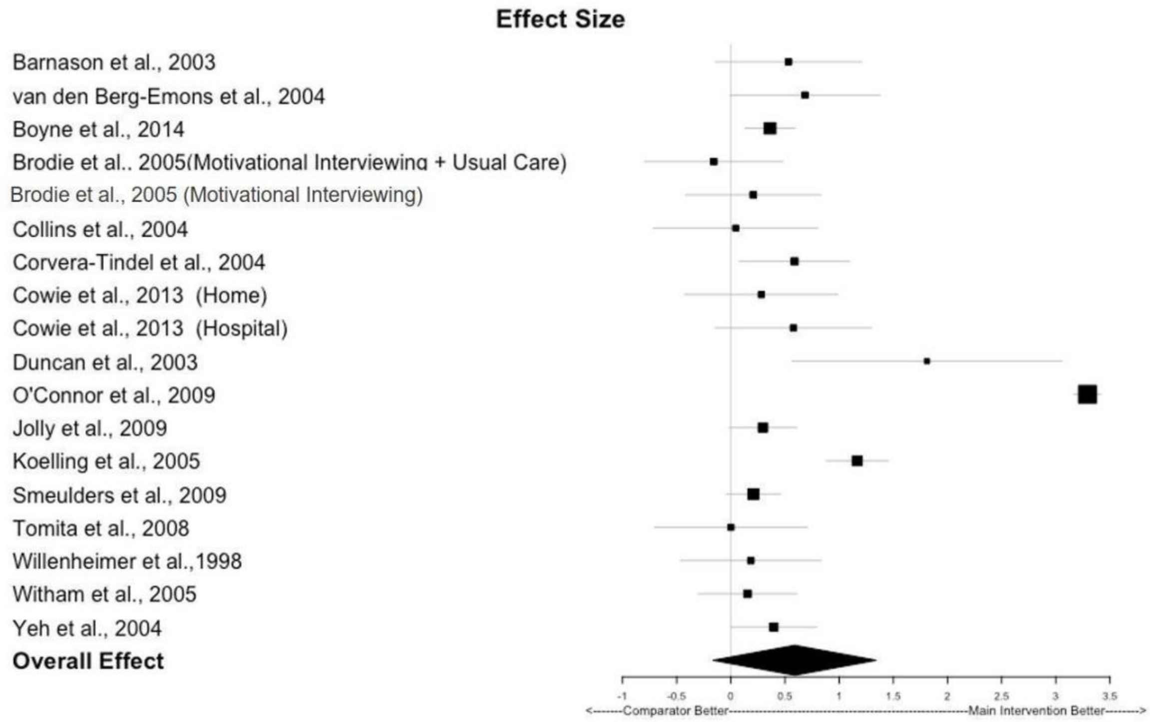

Figure 4.4. Forest plot illustrating effects (SMD) and 95 %CI achieved by the identified studies and the overall effect observed in this meta-analysis.

4.6.9 Impact of participant characteristics on efficacy

Efficacy was negatively associated with the mean age of the intervention participants, β = - 0.06, *95%CI* :[-0.12, -0.01]. Intervention efficacy was not associated with mean LVEF (%), gender, NYHA (Appendix H).

4.6.10 Impact of intervention characteristics on efficacy

3.1.1.2 General approaches

Meta-analysis suggested that the following general approaches were efficacious in improving physical activity a measured post-intervention: *Exercise and Behaviour Change* (Duncan & Pozehl, 2003; O'Connor et al., 2009), *Exercise* (Berg-Emons et al., 2004; Collins et al., 2004; Corvera-Tindel et al., 2004a; Cowie et al., 2011; Willenheimer et al., 2001; Witham et al., 2005; Yeh et al., 2011); *Education* (Koelling et al., 2005); and *Remote Monitoring and Feedback* (Barnason et al., 2003; Boyne et al., 2014; Tomita et al., 2008). *Motivational Interviewing* (Brodie & Inoue, 2005; Brodie et al., 2008) and *Self-Management Programme* (Smeulders et al., 2009a) were not efficacious. The forest plot illustrating the efficacy of the approaches is provided in Figure 4.3.

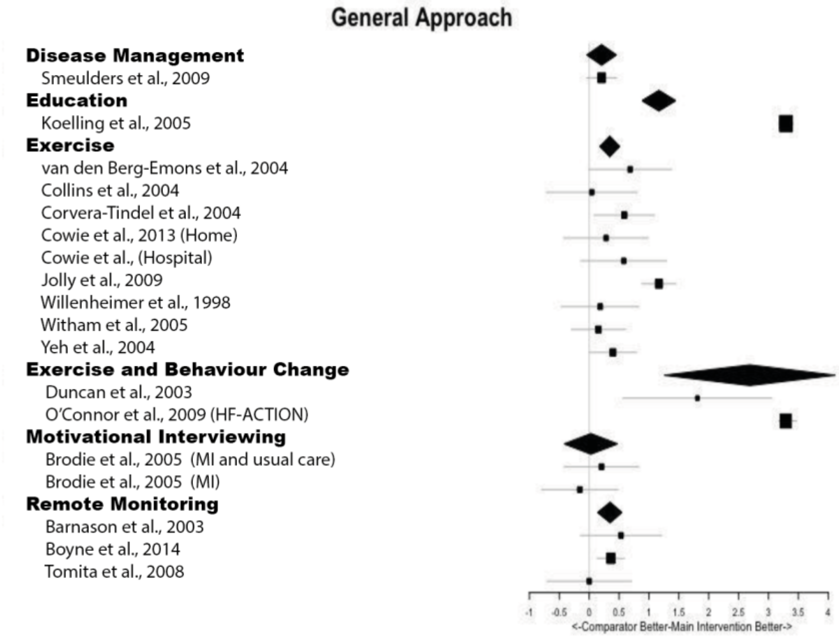

Figure 4.5. Forest plot illustrating effects (*SMD*) and 95%*CI* achieved by each general approach.

Intervention approaches varied significantly in the extent to which they increased physical activity (Q=44.68, p<0.001). Table 4.2 presents the effect sizes (*SMD*) associated with each general approach and comparison of the effect size associated with an intervention type to the effect size of the rest of included trials (Z-test). The differences in efficacy between *Exercise*, *Motivational Interviewing*, *Remote Monitoring and Feedback*, and *The Self-Management Programme* were non-significant (Table 4.5). *Exercise and Behaviour Change* was found to be significantly more efficacious than the rest of the approaches (*Diff. in SMD* = 2.31, *Z-value* =3.15, p<0.0.01).

Table 4.2. **Differences in the efficacy of general approaches.**

	Approach present				Approach not present				Comparative efficacy		
	N	*Num. studies*	*SMD*	*variance*	*N*	*Num. studies*	*SMD*	*variance*	*Diff. SMD*	*Z value*	*p-value*
Education	107	1	1.17	0.17	1954	17	0.55	0.02	0.61	1.38	0.166
Exercise	317	7	0.34	0.35	1743	12	0.82	0.01	0.33	0.56	0.577
Exercise and behaviour change	1166	2	2.69	0.01	895	16	0.38	0.53	2.31	3.15	**0.002**
MI	60	2	0.03	0.17	2001	18	0.66	0.05	-0.63	-1.35	0.178
Remote monitoring and feedback	234	3	0.35	0.11	1827	15	0.65	0.19	-0.30	-0.66	0.508
Self-management	186	1	0.21	0.16	1875	17	0.61	0.02	-0.40	-0.96	0.339

Note: *k* – number of interventions; *SMD* – effect size in comparison to the control group; variance - variance of the effect size; diff (*SMD*) – difference in the effect sizes between interventions general approach is used versus where that approach is not used).

In addition to the differences between general intervention approaches, significant within-subgroups heterogeneity (Q=58.53, p<0.001) was also present. This indicated that other aspects of the interventions may have also contributed to the variance in efficacy.

3.1.1.3 Facilitator, settings, and mode of delivery

Effect sizes (*SMD*) did not differ across intervention settings (home-based/centre-based/both), different facilitators or different modes of delivery. Results are reported in Table 4.3.

Table 4.3. Efficacy of intervention settings, facilitator and mode of delivery.

Intervention Characteristic	Present				Not present				Comparative efficacy			
	n	*k*	*SMD*	*Variance*	*n*	*k*	*SMD*	*Variance*	*Diff SMD*	*Diff SE*	*Z-value*	*p-value*
Facilitator												
Researcher	60	2	0.03	0.05	2001	16	0.66	0.17	-0.49	0.47	-1.35	0.1778
Self-applied	19	1	0.00	0.13	2042	17	0.62	0.16	-0.47	0.54	-1.16	0.2449
Physiotherapist	1243	4	0.99	1.16	818	14	0.44	0.01	-0.43	1.08	0.51	0.6119
Exercise instructor	174	4	0.35	0.01	1887	14	0.65	0.21	-0.44	0.47	-0.63	0.5310
Nurse	159	3	0.67	0.10	1895	15	0.59	0.21	-0.38	0.55	0.16	0.8725
HF nurse	497	4	0.27	0.01	1564	14	0.71	0.21	-0.50	0.47	-0.94	0.3472
Settings												
Mixed settings	1528	7	0.89	0.11	533	11	0.33	0.01	-0.32	0.34	1.66	0.0962
Home-based	435	8	0.32	0.01	1626	10	0.85	0.32	-0.53	0.57	-0.94	0.3476
Centre-based	1528	7	0.89	0.47	533	11	0.33	0.01	-0.32	0.69	0.82	0.4140
Mode of delivery												
Group	1499	8	0.84	0.49	562	10	0.42	0.01	0.42	0.718	0.59	0.5564
Individual	308	6	0.48	0.05	1753	12	0.66	0.28	-0.18	0.57	-0.32	0.7493
Telemonitoring	215	2	0.38	0.18	1846	18	0.61	0.01	-0.23	0.44	-0.52	0.6052

Note: k – number of interventions; SMD – effect size in comparison to the control group; variance of the effect size; diff (SMD) – difference in the effect sizes between the groups (a characteristic is present vs. characteristic is not present).

3.1.1.4 Theory use

It was found that intervention effect (*SMD*) was significantly and positively associated with the total TCS score, β=0.14, 95% *CI*: [0.0069; 0.275], p<0.04. Therefore, greater use of theory (total TCS score) is associated with larger efficacy in increasing physical activity levels. The R^2 indicated that the use of theory explained 21% of the variance in *SMD*. The magnitude of the relationship between the *SMD* in physical activity and the TCS total score was found to be moderate (Ln (RR) =0.40). This suggests that theory use moderately contributes to the interventions' efficacy. Considerable heterogeneity was present (Q=647.57, df=16, p<0.001, I^2>90%), suggesting that other factors may have also contributed to the variance in the interventions' efficacy. The scatter plot of the TCS score regressed onto *SMD* is included in Appendix I.

Most trials did not employ any theory in their intervention design. The *SMD* for these trials varied from 0 to 1.5. When a theory was mentioned but not used excessively (score 2), it had the same effect as interventions that did not mention a theory. Only four other trials used theory to a greater extent (TCS>2) and two of them were more efficacious. This included HF-ACTION which scored 7 and achieved a large effect (*SMD* = 3.29, *95% CI*:[3.17; 3.42]).

3.1.1.5 Contact time

The average contact time of efficacious and inefficacious interventions was 2780 minutes (*SD*=1543.63) and 1333.93 minutes (*SD*=1487.78), respectively. The association between contact time and efficacy (*SMD*) was non-significant (β=0.00, p=0.94).

3.1.1.6 Behaviour change techniques

The effect sizes associated with individual BCTs are displayed in Table 4.4. The effects were significantly larger when the following BCTs were present: Adding objects to the environment (e.g., treadmill) (*Diff SMD*=2.05), Credible source (*Diff SMD*=1.89), Monitoring of behaviour by others without feedback (Diff SMD= 1.64). The effect was significantly smaller when interventions included Problem solving (Diff SMD=-0.50).

Table 4.4. The association between the efficacy and BCTs.

BCT name (code number within BCTTv1)	Efficacy associated with interventions where BCT is present (and not present)					Difference in the Efficacy (BCT present – BCT not present)			Heterogeneity	
	present	n	k	SMD	95% CI	Diff (SMD)	Z-value	p-value	I^2	p-value
Adding objects to the environment (12.5)	present	1174	2	1.99	1.16; 2.82	1.56	3.46	<0.001	98.54	<0.001
	not present	803	16	0.42	0.12; 0.73				65.26	<0.001
Action planning (1.4)	present	1582	10	0.78	-0.40; 1.95	0.38	0.6	0.55	99	<0.001
	not present	479	8	0.4	0.06; 0.74				77.91	<0.001
Body changes (12.6)	present	327	4	0.36	0.08; 0.65	-0.21	-0.44	0.66	53.33	0.09
	not present	1734	14	0.57	-0.33; 1.48				98.66	<0.001
Behavioural practice/rehearsal (8.1)	present	1660	12	0.71	-0.34; 1.75	0.31	0.54	0.59	98.89	<0.001
	not present	401	6	0.4	-0.04; 0.84				82.71	<0.001
Credible source (9.2)	present	1266	2	2.25	1.25; 3.25	1.89	3.46	<0.001	99.45	<0.001
	not present	795	16	0.36	-0.03; 0.74				0	0.54
Demonstration of the behaviour (6.1)	present	390	7	0.32	0.14; 0.51	-0.31	-0.58	0.56	15.71	0.31
	not present	1671	11	0.63	-0.40; 1.67				98.89	<0.001
Feedback on behaviour (2.2)	present	212	3	0.45	-0.25; 1.15	-0.13	-0.23	0.82	69.84	<0.05
	not present	1849	15	0.58	-0.26; 1.43				98.72	<0.001

Goal setting (behaviour) (1.1)	present	1581	12	0.79	-0.19; 1.77	0.53	1.05	0.29	98.66	<0.001
	not present	480	6	0.26	0.11; 0.41				0	0.58
Graded tasks (8.7)	present	1459	10	0.55	-0.66; 1.77	-0.01	-0.01	0.99	98.82	<0.001
	not present	534	8	0.56	0.23; 0.89				79.77	<0.001
Generalisation of target behaviour (8.6)	present	1227	4	1.39	-0.68; 3.46	0.99	0.93	0.35	98.71	<0.001
	not present	834	14	0.4	0.19; 0.60				65.66	<0.001
Information about health consequences (5.1)	present	1931	12	0.6	-0.35; 1.55	0.14	0.27	0.79	99.06	<0.001
	not present	130	6	0.46	0.11; 0.81				34.64	0.18
Instruction on how to perform the behaviour (4.1)	present	1497	9	0.7	-0.46; 1.87	0.37	0.61	0.54	98.89	<0.001
	not present	564	9	0.34	0.15; 0.53				31.98	0.16
Monitoring of behaviour by others without feedback (2.1)	present	78	2	2.04	1.12; 2.95	1.64	3.3	<0.001	99.04	<0.001
	not present	1983	16	0.39	0.05; 0.74				65.7	<0.001
Problem solving (1.2)	present	264	4	0.2	-0.01; 0.41	-0.5	-1.09	<0.001	0	0.54
	not present	1809	14	0.7	-0.18; 1.58				98.75	<0.001
Social Comparison (6.2)	present	60	2	0.02	-0.80; 0.48	-0.64	-0.52	0.6	0	<0.001
	not present	1778	16	0.66	-0.13; 1.45				98.75	0.42
Self-monitoring of behaviour (2.3)	present	1674	11	0.68	-0.40; 1.77	0.21	0.35	0.72	98.89	<0.001
	not present	387	7	0.47	0.06; 0.88				15.71	0.31
Self-monitoring of outcome(s) of behaviour (2.4)	present	1396	4	1.14	-0.84; 3.12	0.74	0.5	0.61	99.46	<0.001
	not present	665	14	0.4	0.16; 0.64				70.1	<0.001
Social support (emotional) (3.3)	present	1219	3	1.13	-1.47; 3.72	0.68	0.52	0.61	65.29	<0.001

	not present	842	15	0.44	0.24; 0.65				98.95	<0.001
Social support (unspecified) (3.1)	present	1530	6	0.67	-0.93; 2.28				99.42	<0.001
	not present	531	12	0.52	0.27; 0.78	0.15	0.18	0.86	64.69	<0.001
Heterogeneity:					**I^2 across BCTs**	**98.64**	**<0.001**			

Note: n – number of participants; k – number of interventions; SMD –standard difference in means; effect size in comparison to the control group; variance of the effect size; Diff (SMD) – difference in the effect sizes between the groups (BCT is present vs. BCT is not present); I2 - the measure of the degree of heterogeneity.

4.6.11 Long-term efficacy

Seven interventions (Barnason et al., 2003b; Duncan & Pozehl, 2003; Jolly et al., 2007; O'Connor et al., 2009; Smeulders et al., 2009; Willenheimer et al., 1998; Witham et al., 2005) had follow-up assessments: two at 3 months after the intervention ended (Barnason et al., 2003b; Duncan & Pozehl, 2003), three at 6 months (Smeulders et al., 2009; Willenheimer et al., 1998; Witham et al., 2005), three at 12 months (Jolly et al., 2007; O'Connor et al., 2009; Smeulders et al., 2009) and one at 30 months after the intervention ended (O'Connor et al., 2009). However, the efficacy at the 3-month follow-up could not be assessed due to lack of reported detail.

The meta-analysis of follow-up physical activity suggested that at 6 months effect on physical activity was non-significant, *SMD*=-0.18 (95% *CI:* [-1.11; 0.75], *p*=0.71). The intervention evaluated in HF-ACTION (O'Connor et al., 2009) was efficacious at 12-month follow-up. The combined effect at 12-month follow-up was also non-significant, *SMD*=0.58 (95% *CI*: [-0.7; 1.86], *p*=0.37). Forest plots illustrating the long-term efficacy at 6 months and 12 months after completion are provided in Figure 4.4 and Figure 4.5.

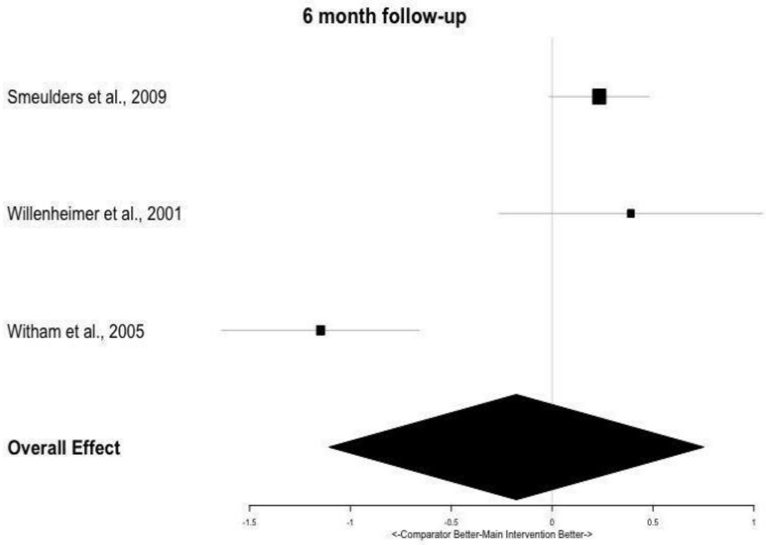

Figure 4.6. Forest plot illustrating effects (SMD) and 95% CI for each study and the overall effect as assessed at 6-month follow-up.

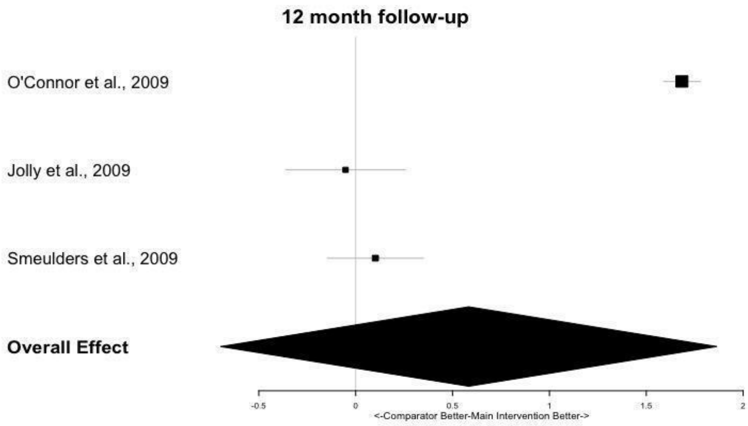

Figure 4.7. Forest plot illustrating effects (SMD) and 95% CI for each study and the overall effect as assessed at 12-month follow-up.

4.6.12 Sensitivity analysis

The comparator treatment varied across included studies, presenting a considerable bias. Therefore, to evaluate the impact of this bias, a sensitivity analysis was performed. It showed non-significant differences in efficacy between trials comparing the main intervention group to education (Boyne et al., 2014; Brodie & Inoue, 2005), exercise training (Duncan & Pozehl, 2003), HF specialist nurse care (Jolly et al., 2007), or usual care (Barnason, 2003; Berg-Emons et al., 2004; Collins et al., 2004; Corvera-Tindel et al., 2004a; Cowie et al., 2011; Koelling et al., 2005; O'Connor et al., 2009; Smeulders et al., 2009; Tomita et al., 2008; Willenheimer et al., 1998; Witham et al., 2005; Yeh et al., 2011).

4.6.13 Publication bias

The classic case of publication bias is when there are small trials that have significant effects while large trials do not. In this case one expects other small trials with negative results really do exist, however were omitted from the analysis because they were not published. In such situations, a funnel plot and the Trim and Fill method are appropriate for diagnosing the extent of publication bias. However, the present meta-analysis showed the opposite pattern. The small trials did not show large effects. Instead a single large (N=2331) well-funded trial (HF-ACTION) reported a larger effect than other trials. Therefore, the funnel plot is distorted by the presence of the HF-ACTION trial and should be disregarded (the funnel plot is still reported in Appendix A).

4.7 Discussion

The present review identified and evaluated existing interventions designed to increase physical activity in HF. Sixteen randomised controlled trials (RCTs) of 18 interventions were included. Overall, when combined in meta-analysis, the set of existing interventions did not appear to be efficacious in increasing physical activity in HF. However, the effects of individual interventions varied. Some effects were extremely small (*SMD*=0.03 for Motivational Interviewing), while other were large (*SMD*=2.69 for Exercise and Behaviour Change). Long-term efficacy of the evaluated interventions was not supported by this systematic review and meta-analysis. However, the evidence for this was sparse since only three trials included 6-month and 12-month assessments. Another result was that efficacy was negatively associated with the mean age of the trial samples. This suggests that the existing interventions are particularly ill-fitted for promoting physical activity in HF in older adults (>70). Finally, a number of other intervention characteristics were suggested to be promising in promoting physical activity in HF. These will be discussed in detail below.

4.7.1 What approach is most promising in promoting physical activity in HF?

Exercise and Behaviour Change was found to be more efficacious that the rest of the evaluated approaches in the present meta-analysis. This includes the approach *Exercise* alone. The important implication is that engagement in supervised physical activity that results in improved physical capacity to establish an active lifestyle, is necessary but not enough.

Exercise-based programmes have been found in several reviews to have positive short-term effects on hospitalisation and HRQoL (Davies et al., 2010; Lewinter et al., 2015; Sagar et al., 2015; Taylor et al., 2014). These reviews have reported that exercise programmes are effective in the short-term (Davies et al., 2010; Lewinter et al., 2015; Sagar et al., 2015; Taylor et al., 2014), but their effects diminish 12 months after the programmes cease (Sagar et al., 2015). One explanation is that physical activity is not sustained after the programme is discontinued. This leads to deconditioning of the heart (Piña, 2003).

Improved exercise capacity achieved by exercise programmes is often expected to be enough to promote an active lifestyle. However, this is not the case. For instance, exercise programmes in this review elicited significant improvements in exercise capacity but failed to initiate an active lifestyle (Van den Berg-Emons et al., 2004: Willenheimer et al., 1998). Although these exercise programmes provided participants with the physical capacity to become more active, individuals with HF did not change their physical activity behaviour outside the intervention.

However, substantial risk of bias is present across included trials as will be discussed in detail below. High quality evidence on the efficacy of *Exercise and Behaviour Change, Remote*

Communication & Feedback, and *Exercise* in promoting physical activity in older adults with HF is needed before drawing definitive conclusions.

4.7.2 Which behaviour change theory is key in promoting physical activity in HF?

The present systematic review and meta-analysis suggests that interventions that are informed by a theory are more likely to be efficacious. This is in line with other meta-analyses suggesting that theory-informed interventions are more efficacious in increasing physical activity than others (Taylor et al. 2012).

The included trials evaluated interventions informed by Social Cognitive Theory (Bandura, 1997), the Transtheoretical Model of Change (Prochaska & DiClemente, 1986), and Motivational Interviewing (Miller & Rose, 2009). Two trials combined several theories in informing the interventions: Social Cognitive Theory (SCT) and Transtheoretical Model of Change (TTMC) (O'Connor et al., 2009); and a combination of SCT, Support Theory and Communication Theory (Tomita et al., 2008). The combination of SCT and TTMC was found to be efficacious in promoting short-term physical activity in younger (mean age = 56) adults with HF. This suggests that the interventions that combined theories were more efficacious than single-theory interventions. While focusing on a single theory may be the best way to develop its evidence base, it may not be the best way to design an effective intervention. Instead, combining multiple theories may be a more promising approach.

Although it was found that the extent to which interventions were informed by theory was associated with greater efficacy, the trials included in the present review are limited in the ways theory was applied. First, there was a lack of theory-informed interventions across the reviewed trials. Only in 7 out of 18 interventions a theory was used to inform the intervention. The use of theory in the design of these seven interventions was also limited, meaning that the content of these interventions identified as theory-informed, was often poorly guided by a theory, as reflected by the TCS score. Interventions did not clarify the link between the applied BCTs, and the theoretical components being targeted. In addition, there are many theories (Davis, Campbell, Hildon, Hobbs, & Michie, 2015) that could form the basis to an efficacious physical activity intervention, yet only three theories (SCT; TTMC; Motivational interviewing) were assessed across the included trials.

The method of choosing these theories for improving physical activity in HF was not clear. The trials included in the present review did not report in full what barriers and enablers the interventions under investigation were attempting to address and did not clarify how these barriers were addressed. This is a persistent problem in behaviour change research (Lippke & Ziegelmann, 2008). It is necessary to explore what must change before designing a physical activity intervention, and based on that, to form a theoretical foundation on which to choose intervention content (described in Chapter 3).

4.7.3 What intervention characteristics are promising in promoting physical activity in HF?

Intervention setting, facilitator, and mode of delivery did not have an impact on the efficacy of the reviewed interventions. It has also been previously supported by a meta-analysis that home-based cardiac rehabilitation is more efficacious than usual care in terms of improving the clinical outcomes of the condition, and therefore can serve as an alternative to centre-based cardiac rehabilitation in aiding HF management (Zwisler et al., 2016). On the other hand, three meta-analysis of rehabilitation settings found that home-based and centre-based cardiac rehabilitation programmes are equally effective in improving survival, quality of life, and exercise capacity for individuals with angina, myocardial infarction, and HF (Taylor et al., 2015; Anderson et al., 2017; Dalal, Zawada, Jolly, Moxham, & Taylor, 2010). Authors also concluded that this finding, together with the absence of evidence of differences in healthcare costs between the two approaches suggests that the choice of participating in a more traditional and supervised centre-based programme or a home-based programme should reflect the preference of the individual patient (Taylor et al., 2015). The findings of the present meta-analysis suggest that both settings are equally ineffective in promoting physical activity. Therefore, CR and exercise programmes are efficacious in improving clinical outcomes in HF, but an additional intervention content is required to improve physical activity in HF and to maintain these clinical benefits once CR is ceased.

Contact time was not found to be crucial to intervention efficacy. This has implications for cost-effectiveness of the existing interventions, as this review suggests it might be more important to offer the appropriate content of an intervention (BCTs, general approach) rather than resource-intensive and lengthy interventions. However, these findings are tentative, given the small number trials and the reviews' other limitations described below.

The findings of the present meta-analysis suggest that the majority of existing BCTs were not reported to be included in the intervention content. A small number of BCTs were suggested to be associated with efficacy. 'Adding objects to the environment', 'Credible source' and 'Monitoring of behaviour by others without feedback' were more efficacious than interventions that did not include these BCTs. The findings on each of these characteristics are discussed separately below.

'Credible source', defined as 'Presenting verbal or visual communication from a credible source (health professional) in favour of engaging in physical activity', was included in two interventions (Koelling et al., 2005; O'Connor et al., 2009). *Credible source* was only coded as present in the intervention when there was a description of an explicit advice being provided to individuals with HF.

For instance, in an intervention evaluated in the HF-ACTION trial, the '*Credible source'* BCT was delivered in a form of a formal prescription for physical activity by a healthcare professional, based on the guidelines provided in Exercise Standards For cardiac patients (Fletcher, Froelicher, Hartley, Haskell, & Pollock, 1990). It included explicit rationale for engaging in physical activity, and advice on adjusting the intensity according to environmental conditions (weather), physical capability and symptoms, as well as reassurance that breathing is elevated during exercise, however, should not cause discomfort. In one-to-one education sessions delivered by a nurse targeting several self-care behaviours and symptom monitoring evaluated by Koelling et al.,(2005), the '*Credible source'* strategy entailed an explicit advice and rationale for engaging in physical activity provided in a one-to-one session with a nurse. In addition, a leaflet summarising guideline on HF treatment in lay terms was handed out to the participants. Therefore, advice to engage in physical activity is efficacious when provided rigorously and explicitly, as suggested by the present meta-analysis.

'Credible source' has been grouped by the expert panel into the 'Comparison of outcomes', which has been linked to *Beliefs about Consequences* and Attitudes toward the behaviour (Conell et al., 2018). Thus, it could be the case that receiving explicit advice from a trusted source such as a health professional may strengthen belief in the positive outcome of engaging in physical activity and encourage an individual with HF to be more active.

'Monitoring by others without feedback' has been categorised as 'Feedback and monitoring' and is deemed by an expert panel (Connel et al., 2018) to target *Behavioural Regulation* domain. It is possible that BCTs that have been isolated as efficacious promote physical activity by bringing about a positive change in *Behavioural Regulation*. The efficacy of both *Credible source* and '*Monitoring of the behaviour by others without feedback*' are in line with a suggestion that improved patient-clinician communication through means of telemonitoring may be empowering and lead to better outcomes in terms of QoL, hospitalisation, and mortality (Anker et al. 2011). It was previously found that intensive management of patients with HF improves the quality of care, has a positive impact on quality of life, and reduces readmissions through frequent monitoring, detailed assessment, optimization of medications, and education (Rich et al., 1995). Another systematic review in the literature also suggested that provision of disease management programme by a multidisciplinary team where an emphasis is placed on patient education and importance of self-management is associated with improved survival and reduced hospitalisation (McAlister, Stewart, Ferrua, & McMurray, 2004). Likewise, the present review supports the importance of patient-clinician communication in promoting physical activity.

'Adding objects to the environment' was identified as a promising strategy for increasing physical activity levels. The objects that were provided were a treadmill or a stationary bike. These findings suggest that altering the environment and providing physical resources that encourage physical activity is potentially efficacious in the short-term. *'Adding objects to the environment'* may effectively target the *Environmental Context and Resources* domain (Conell et al., 2018). Specifically, it promotes physical activity through providing resources and an opportunity to

exercise. It involves identifying which environmental resources are important for promoting a physically active lifestyle. However, this strategy is expensive and might not be feasible to implement in everyday life for many patients with HF. Furthermore, it must be borne in mind that the evidence supporting the efficacy of this BCT is weak, as it was only present in two trials.

One BCT that was present in significantly less efficacious interventions is *'Problem solving'*. A recent large review and expert panel study did not link this BCT to any of the theoretical domains (Conell et al., 2018). One assumption that needs further investigation is that focusing attention on potential barriers may discourage physical activity in people with HF who already face many difficulties.

Overall, this review identified a lack of breadth of research into strategies to promote physical activity. Currently, there are 93 known BCTs that can be potentially applied to promoting physical activity, and only 20 BCTs were encountered in the reviewed trials, three of which were found to improve efficacy and one was found to have a negative impact. Given the small number of BCTs being assessed, there is a lack of breadth of evidence on what BCTs might be efficacious in improving physical activity.

The small number of BCTs being assessed for its efficacy in promoting physical activity in older or chronically ill adults in general. As such 23 BCTs were used in interventions to increase physical activity in older adults (French et al., 2014), 13 in people with dementia (Nyman, Adamczewska, & Howlett, 2017), 26 in relatively young (mean age was 59 years old) cardiac patients (Ferrier, Blanchard, Vallis, & Giacomantonio, 2011), While 40 BCTs were used in physical activity interventions for younger adults (Samdal, Eide, Barth, Williams, & Meland, 2017) and 36 for adolescents (Hynynen et al., 2016). This trend suggests a smaller number of BCTs being applied in interventions for the chronically ill and old population compared to other segments of the population.

4.7.4 Interventions' target group

Age, gender, NYHA class, and LVEF (%) were tested as predictors of intervention success in improving physical activity. The efficacy of the interventions was negatively correlated with the mean age of the participant sample, whereas gender, NYHA class and LVEF were not. The currently existing interventions, therefore, seem to be especially ill-fitted for promoting physical activity in older adults (>70) living with HF. The identified trials have tested the efficacy of interventions in a younger HF population (the mean age was 67 years old). Individuals younger than 70 years old were recruited in eleven out of 16 trials and constituted 82.2% of the total sample of the present meta-analysis.

Older adults with HF constitute most of the HF population, and their numbers are continually increasing as outlined in Chapter 2. The clinical profiles of older adults differ from younger adults, including a significantly worse prognosis and a larger number of comorbidities (Butrous and Hummel 2016). Older adults with HF are especially at risk of sedentary behaviour (Evangelista et al., 2003; Gonzalez et al., 2004; Chien et al., 2014) and therefore, are the risk group that should be targeted by behaviour change interventions. Finally, a previous review of physical activity interventions found that strategies known to be efficacious in the general population (Carver and Scheier 2012); Greaves et al., 2011; McEwan et al., 2016; Williams & French, 2011) are not suitable for a non-clinical older population (> 70 years old; French, Olander, Chisholm, & McSharry, 2014). These include strategies that improve self-regulation, such as setting behavioural goals, prompting self-monitoring of behaviour, planning for relapses, providing normative information, and providing feedback on physical activity. Therefore, older adults may also differ in their beliefs about physical activity and experience barriers and enablers distinctly differently to those experienced by the younger population.

Older adults are under-represented in the trials included in this review. Therefore, future research is recommended to focus on tailoring interventions to older adults with HF and to include them in trials evaluating physical activity interventions.

4.7.5 HF-ACTION

The findings of the present review should be considered in light of the large influence of the HF-ACTION trial (O'Connor et al., 2009; Whellan et al., 2007). A large proportion (37%) of the meta-analysis sample was drawn from this trial. This trial is also an outlier in the set of included trials in that it reported larger effects than the rest.

This could be due to a number of reasons: 1) a large participant sample provided enough statistical power to detect an effect; 2) the trial was better funded, which may have improved both the delivery of the intervention and its fidelity; 3) considerably younger people with HF were included in the trial (the mean age of the sample was 59 years calling its representativeness into question; 4) a great amount of tailoring and flexibility was present in the design of the intervention Participants, for example, were trained in performing a modality of activity of their choice (walking; cycling; running), at an intensity matching their physical capacity; 5) it used an intensive facility-base, access to ergometers; rowing machines; cycling; and treadmills was provided to participants.

The HF-ACTION trial suggested that *Exercise and Behaviour Change*, theory use and a few other BCTs improve physical activity. The physical activity effect was also maintained at 12 months. However, the trial included young adults (mean age=59 years old). Therefore, it suggests that the intervention is likely to be efficacious only for this particularly unrepresentative demographic group. It might not be efficacious for older adults. Therefore, it is critically important to investigate barriers and enablers to physical activity faced by older adults diagnosed with HF. In addition, given that participants were recruited to take part in an exercise programme, it is likely that the trial included adults willing to exercise in the first place potentially introducing a selection bias. It is not known whether the intervention would be equally efficacious for adults lacking an intention to exercise.

Sensitivity analysis indicated that exclusion of the trial diminishes the importance of strategies other than exercise training, the gradual increase in exercise intensity and group- and centre-based delivery by the physiotherapist. The trial also contributed to the estimate of the effects achieved by *Exercise and Behaviour Change* approach. The observed greater efficacy of HF-

ACTION could be due to the likely true effect of the intervention and associated intervention characteristics. On the other hand, HF-ACTION was a well-funded trial, which may have improved the delivery of the intervention and intervention fidelity. The trial also included a considerably younger sample (56 years old) than the general population (80 years old, National HF Audit, 2018) and utilised an intensive facility (ergometers; rowing machine; cycling; treadmills). These properties may jeopardise the ecological validity of the findings of this meta-analysis, as well as bias the evaluation and overestimate the efficacy of several identified characteristics.

4.7.6 Limitations of the included trials

A large proportion of the screened trials satisfied the first two criteria for inclusion in the present review but did not report levels of physical activity as the study outcome. Future trials evaluating exercise programmes are encouraged to measure physical activity that takes place outside an intervention to build an evidence base for the approaches and strategies effective in promoting a physically active lifestyle.

The trials included in this review were evaluated in terms of risk of bias using a standardised and validated risk of bias tool (Higgins et al., 2011a). A moderate risk of bias was identified across the included trials. This may compromise the intrinsic validity of the findings. The physical activity outcome was evaluated using self-reports in most trials. Self-reports overestimate actual physical activity levels (Kowalski, Rhodes, Naylor, Tuokko, & MacDonald, 2012). The strength of evidence would be improved if trials included objective assessment of physical activity levels using pedometers and accelerometers as they are a more accurate measure of physical activity levels (Kowalski et al., 2012).

Trials did not report for how long the participants had been diagnosed with HF when the interventions took place. People with newly diagnosed HF experience higher levels of fatigue (Williams, 2017), and are more likely to be hospitalised (Greene et al., 2017), and experience alterations to their pharmaceutical treatment (Johansson, Wallander, Ruigómez, & Rodríguez, 2002). The impact of this possibility should be considered when deciding on the timing of a physical activity intervention. On the other hand, implementing an intervention at a later point after diagnosis, when habitual sedentary behaviour might have already been established, could be challenging.

The reviewed trials did not assess the relationship between physical activity levels and health outcomes., This makes it difficult to interpret the obtained changes in physical activity in terms of their clinical significance (Shoemaker, Curtis, Vangsnes, & Dickinson, 2013). Such interpretation would require one to estimate the impact the positive change in physical activity has on hospitalisation, QoL and mortality. But these additional outcomes were not assessed.

Participants across trials were diagnosed with HF with reduced ejection fraction (HFrEF) and were male and younger than the general HF population, limiting the generalisability of the findings. Older adults (>70) remain underrepresented in trials evaluating interventions to promote physical activity in HF even though the mean age when one is diagnosed with HF is 80 years old (British Heart Failure Audit, 2018). Future research should focus on optimising physical activity in older adults living with HF. Hence, the remainder of this project is concerned with producing an evidence base for improving physical activity in people with HF of 70 years and older.

4.7.7 Strengths of the review

AMSTAR 2 (Appendix B; Shea et al., 2017) was used to evaluate biases that may have been introduced during the conduct of this review. Several measures were taken to improve the methodological rigour of this review and to strengthen the validity of the findings. Firstly, the review followed the PRISMA guidelines (Panic et al., 2013). Secondly, to overcome reporting bias, the design and procedure for the review were described a priori and published in an online protocol. The research questions and inclusion criteria were defined before the initiation of the review and published online. This review identified a lack of uniformity across trials in physical activity assessment. It was overcome by producing standardised mean differences estimates.

A comprehensive literature search across nine databases was performed. The search strategy was discussed with a professor of cardiology who specialises in HF and included MESH terms and keywords used in the search strategy of past reviews that were commenced to produce NICE guidelines on HF management (2010). Secondly, the bibliography of the included trials was also screened for further potentially relevant trials. Thirdly, grey literature was also searched. Finally, the researchers searched for reports regardless of their publication type.

The utilisation of the Behaviour Change Techniques Taxonomy (Michie, 2013b) ensured that the content of the reviewed interventions was systematically documented. The use of the coding system helped classify the interventions and facilitated the analysis of which of their characteristics were associated with greater intervention efficacy.

The included trials operationalised diverse definitions and measures of physical activity (i.e. steps; accelerometer counts; self-reports; number of exercise sessions). The use of standardised mean differences mitigated this limitation. Only a small number of trials evaluated some of the individual intervention characteristics. The recommendation to adjust for uncertainty introduced by a small number of studies was followed (Debray et al. 2017).

A sensitivity analysis was performed to mitigate the following limitations. A risk of bias was observed in one trial (Tomita et al., 2008). The sensitivity analysis indicates that the inclusion of these trials may underestimate the efficacy of the *Remote Monitoring and Treatment*. The comparator treatments also included an active intervention in five RCTs. The trials compared the main intervention to a range of treatments, such as usual care, education, HF specialist care, and an aerobic exercise programme without a theory-based behaviour change intervention, which may have confounded the observed efficacy. A sensitivity analysis was performed to test whether the differences in the comparator treatment across trials influenced findings. It indicated that this bias results in underestimation of the effect; however, the difference in the derived effect size was not significant.

4.7.8 Limitations of the review

Before drawing any conclusions about the efficacy of behavioural interventions in increasing physical activity in HF, the following limitations should be considered. Markedly different interventions were combined in the overall meta-analysis, which may be inappropriate given the considerable heterogeneity in their efficacy. For this reason, the overall efficacy should be interpreted with caution. To overcome this inherent limitation, the heterogeneity in intervention efficacy was explored. More specifically, groups of similar interventions – general approaches – were evaluated first, and then the characteristics of each intervention that contribute to its efficacy were investigated.

An exploratory meta-analysis like this one may make tentative suggestions on what could constitute an efficacious physical activity intervention. However, by no means does it make causal claims. Meta-analysis probes associations between each characteristic and the observed effect. The efficacy of each intervention characteristic needs to be assessed in an RCT, to be able to identify causal effects.

Each intervention characteristic was evaluated in isolation. This helped pint-point which contributed to efficacy to a greater extent than others. However, this presents a limitation. None of the intervention strategies were applied in isolation. For example, *'Action planning'*, *'Goal setting (behaviour)*' and *'Self-monitoring of behaviour*' were often used conjointly, While '*Demonstration of the behaviour*' was a component of exercise programmes without an accompanying behaviour change intervention 5 out of 7 times. Given the small number of RCTs evaluating any single included characteristics, the multiple comparisons were not feasible. It is not possible to conclude from the present meta-analysis whether each characteristic was sufficient for producing the effect on its own, or if it acted synergistically with other characteristics to produce additive or interactive effects. The one-at-a-time evaluation of a single strategy approach can be considered in future RCTs.

Only the reported descriptions of the interventions were annotated. However, limited descriptions of the interventions were provided within the reports. The description of an intervention was often narrow (Hoffmann et al., 2014). Therefore, coding of the interventions in the present review may not reflect the actual content of interventions and thus introduce a bias.

4.7.9 Recommendations for future research

To the best of the author's knowledge, this is the only meta-analysis of trials that examined interventions' impact on physical activity in HF. For this reason, the results are discussed in comparison to published reviews of the impact of physical activity interventions on other outcomes besides physical activity. Reviews on outcomes such as HRQoL, mortality and hospitalisation included a larger number of trials than the present review, n=33, 33 and 46, respectively (Davies et al., 2010; Lewinter et al., 2015; Taylor et al., 2014; Sagar et al., 2015). There was not a great deal of overlap between the present review and reviews investigating different outcomes because trials included in the reviews on HRQoL, mortality and hospitalisation did not report physical activity outcome and therefore did not meet the inclusion criteria of the present review. Therefore, it is recommended for trials evaluating the effects of physical activity on health outcomes to also include physical activity assessment.

The present review suggests that use of a behaviour change theory in designing a behaviour change intervention is key to ensuring its success in improving physical activity in adults with HF. However, there is both lack of clarity and lack of breadth in theoretically based understanding of the underlying mechanism of the interventions, i.e. the factors that may influence physical activity in HF. A comprehensive understanding of these factors may prove useful in optimising the content of the interventions. Exploration of these factors is the primary focus of this thesis.

The findings of the present systematic review and meta-analysis indicate that existing interventions targeting promotion of physical activity in HF are not efficacious in the long-term. Therefore, it is important to investigate how a sustained positive change in physical activity can be established to secure the benefits of physical activity over longer periods of time.

An understanding of why and how BCIs produce their effects is impeded by the lack of appropriate methods. A meta-analysis offers claims about association not causality. Currently, an ontology is being developed (Michie et. al., 2017; West et al., 2019; Hale et al., 2020). The ontology summarises causal assumptions about BCIs (West et al., 2019) that can be expressed graphically and mathematically. The use of such a structured knowledge system of evidence, and its representation in a computable format facilitates inference about causality. Such ontology in-built into a meta-analysis as a set of assumptions, helps to formulate causal claims and seek evidence supporting them (Michie & Johnston, 2017; West et al., 2019). Furthermore, a detailed knowledge representation helps to gain statistical precision and power (Leeuw et al., 1998; Sterne Higgins et al., 2011; Pearl 2009) for both causal inference and the evaluation of the BCIs' effects. With the help of Machine Learning it might be possible to support or dispute the causal assumptions embedded in this ontology However, a large set of trials would be required for such data hungry methods as Machine Learning.

Many of the BCTs are simultaneously related to several behaviour change theories. Therefore, identifying why a BCT is exhibiting an effect is problematic. BCTs were mapped onto the mechanism of action (i.e the causal chain of events and changes that give rise to the change in the behaviour) in a large review (Carey et al., 2018). The studies reported in Chapter 6 and 7 pursue the exploration of how physical activity in HF is enacted (i.e. mechanism of action) using empirical research and computational modelling. Then a recommendation for what BCTs may be relevant given the identified mechanism of action is made in Chapter 8.

4.8 Conclusion

Overall, the existing physical activity interventions are not efficacious in increasing physical activity in HF. The present review explored intervention complexity and identified some characteristics of potentially promising physical activity interventions designed for people with HF. However, older adults are under-represented by the trials included in this review. Therefore, future research should focus on investigating the barriers and enablers to physical activity experienced by a representative sample as well as on tailoring interventions to older adults with HF.

The present review indicated that applying behaviour change theories is potentially a promising way of designing efficacious interventions. However, the use of theory across the evaluated trials was limited. It remains unclear as to what theory is the most relevant to understanding how physical activity is enacted in HF. To design a successful physical activity intervention, it is necessary to first explore barriers and enablers to physical activity in HF, identify factors influencing the behaviour, the mechanism via which they realise increased physical activity, and the theory descriptive of these processes.

4.9 Addendum

To ensure that the meta-analysis was up to date at the point of submission of this thesis the search was updated on 20 February 2020. The full report is attached in Appendix A. Over 4400 new research articles were identified during screening. A total of seven new randomised controlled trials met the inclusion criteria (Ajiboye et al., 2015; Bernocchi et al., 2018; Dalal et al., 2018; Freedland et al., 2015; Meng et al., 2018; Pozehl et al., 2018; Yong et al., 2016). Accordingly, the studies piloting these interventions were excluded from the updated meta-analysis.

Interventions (n=22) had a significant overall effect (*SMD*=0.54,95% CI: [0.16; 0.93],$p<0.005$) as assessed immediately after the intervention. However, high heterogeneity in the effects was present, warning against the interpretation of an overall effect, I^2=95.79%, Q=1531.74,$p<0.001$).

The additional trials evaluated Cognit*ive-Behavioural Therapy* (n=1; Freedland et al., 2015) *Remote Monitoring and Feedback* (n =1; Bernocchi et al., 2018), *Self-management Programme* (n=1; Young et al., 2016), and *Exercise and Behaviour Change* (n=2; Dalal et al., 2018; Pozehl et al., 2018) at post-completion. *CBT* (Freedland, 2018) and *Self-management Programme* (Young et al., 2018) were not suggested to be efficacious in increasing physical activity in HF.

One additional trial evaluated the long-term effect of the Self-management *Patient Education Programme* but not as assessed post-intervention (Meng et al., 2018). Authors did not find a sustained effect. The inclusion of the study did not change the results of the initial meta-analysis assessing the long-term efficacy of interventions.

The addition of one trial evaluating *Exercise* programme changed the findings regarding the overall efficacy of exercise approach (Ajiboye et al., 2015). However, a large risk of bias was present, including lack of blind assessment and a registered protocol.

Similarly, to the meta-analysis presented in this chapter, '*Credible source'*, '*Adding objects to the environment'*, '*Monitoring of Behaviour by others without feedback'* were suggested efficacious in increasing physical activity in HF. The presence of six BCTs in newly identified interventions were significantly associated with efficacy: '*Prompts/Cues'*, '*Generalisation of target behaviour'*, '*Self-monitoring outcomes of behaviour'*, '*Graded tasks'*, '*Behavioural practice/rehearsal'*, '*Action planning'*, and '*Goal setting'* (SMD and 95% CI are reported in Appendix A).

Basing on the recent research outlining the link between BCTs and mechanism of action (Connell et al. 2018; and Bohlen et al., 2018), it is proposed that the BCTs that were identified to be associated with the efficacy promote physical activity by the means of Behavioural Cueing through restructuring the environment (*Adding Objects to the environment*), physical activity skills acquisition through repetition of the behaviour (*Behavioural practice/rehearsal*), yield formation of positive Attitude Toward the Behaviour (Cre*dible source*), improved Self-regulation (*Goal setting and Self-Monitoring*).

Similarly, to the findings of the exploratory meta-analysis of the trials identified in the initial search, only *Exercise and Behaviour Change* was found to be efficacious (SMD=1.22, 95% CI:[0.04; 2.39]. The newly identified trials evaluating this approach were REACH-HF trial (Dalal et al., 2018) and HEART Camp trial (Pozehl et al., 2018).

The REACH-HF intervention was based on Self-determination Theory, Control Theory and Common-sense Model produced a non-significant effect. The HEART Camp intervention was based on Social Cognitive Theory (SCT) and produced a significant medium sized effect. However, besides being based on a different set of theories, these interventions were evaluated in trials with individuals of different ages. The REACH-HF trial recruited older individuals (mean age = 70) than HEART Camp (mean age =60). The HF-ACTION trial and the newly identified HEART Camp support the efficacy of SCT (with or without TTMC) for increasing physical activity in younger individuals with HF (56 and 60 years old). These trials will be discussed in Chapter 8. It remains unclear how to change physical activity in older adults with HF, who constitute a majority of this clinical population.

5 Barriers and Enablers to Physical Activity in HF: A Bayesian Meta-analysis.

5.1 Introduction

Chapter 2 reported that HF is a complex clinical syndrome of symptoms and signs that suggest reduced efficiency with which the heart pumps blood around the body (National Institute for Healthcare and Excellence, 2018). HF is a prevalent condition worldwide (Vos, Allen, & Arora, 2016) and in the UK (National Institute for Health and Care Excellence, 2018). The clinical outcomes of HF include mortality, morbidity, and reduced quality of life (Hobbs et al., 2002; Taylor, Roalfe, Iles, & Hobbs, 2012).

Physical activity is associated with improved quality of life (Davies et al., 2010; Lewinter et al., 2015; Sagar et al., 2015; Taylor et al., 2019), reduced hospitalisation (Sagar et al., 2015) and increased longevity (Belardinelli, Georgiou, Cianci, & Purcaro, 2012; ExTraMATCH Collaborative, 2004). Physically active lifestyle, therefore, is a component of the recommended treatment (NICE). Exercise is included in cardiac rehabilitation (CR) offered to newly diagnosed HF patients (Jenni et al., 2012).

The uptake of CR programmes among those diagnosed with HF, however, is dramatically low. Less than 1% of the HF population in the UK initiated the programme in 2017-2018 (National Audit of Cardiac Rehabilitation, 2018). Levels of everyday physical activity in HF are low (Jaarsma et al., 2013). This is partially due to the many challenges the individuals with HF face in initiating and maintaining a physically active lifestyle as proposed in the statement by European Society of Cardiology (Conraad et al., 2012).

Chapter 4 reported a meta-analysis of trials evaluating interventions designed to enhance physical activity for people with HF. Overall, identified trials do not inform about how exactly physical activity in HF can be improved. Especially in older adults (>70) with HF who make up the majority of this population.

It is recognised by frameworks for developing behaviour change interventions (Araújo-Soares et al., 2019; Craig et al., 2008; Hankonen & Hardeman, 2020; Kok et al., 2016; S Michie et al., 2014; O'Cathain, Croot, Sworn, et al., 2019) that first the modifiable as well as contextual determinants need to be systematically identified and described before an intervention can be developed. This helps to increase the chances for the intervention to be effective and helps and conserves research effort and resources. However, the determinants of physical activity in HF are not well understood. As such, a systematic review of qualitative studies found a lack of research on individual accounts of barriers and enablers to physical activity (Tierney, Mamas, et al., 2011). The evidence on the factors influencing physical activity in HF is sparse.

Therefore, the evidence-base concerning potential determinants of physical activity is systematically reviewed in this chapter. Bayesian meta-analysis is used for this purpose in line with the recommendation by Dixon-Woods and colleagues (Dixon-Woods et al., 2005, 2006; Roberts et al., 2002). This framework helps in synthesising qualitative and quantitative research. It also helps summarise evidence in a way that is useful for decision-making on what are the relevant barriers and enablers to physical activity in HF.

The determinants of the behaviour are often described inconsistently, especially across epistemologically diverse studies. In the present review, the barriers and enablers to physical activity in HF are identified and categorised in accord with the Theoretical Domains Framework (TDF) (Cane et al., 2012). TDF is described in Chapter 3.

5.2 Rationale for the methodology

Following the call for adaptation of Bayesian statistics in Health Psychology research made by Depaoli and colleagues (Depaoli, Rus, Clifton, van de Schoot, & Tiemensma, 2017) and endorsed by health psychology scientists (Beard & West, 2017; Hamilton, Marques, & Johnson, 2017; Heino, Vuorre, & Hankonen, 2018), this chapter applies Bayesian statistics in secondary research synthesis. While previously this methodology was applied in a randomised control trial evaluating a behaviour change intervention designed to improve physical activity in adolescents (Heino et al., 2018), this meta-analysis implements Bayesian update in synthesising evidence on modifiable determinants to physical activity in HF. Bayesian meta-analysis is carried out in line with the recommendation by Dixon-Woods and colleagues (Dixon-Woods et al., 2005, 2006; Roberts et al., 2002). This framework helps in synthesising qualitative and quantitative research. It also helps summarise evidence in a way that is useful for decision-making on what are the relevant barriers and enablers to physical activity in HF.

Bayesian methods are especially useful when evidence from diverse sources must be integrated (Spiegelhalter et al., 2004). Qualitative research is often easily available from research studies on health and health management; however, its findings are often not utilised in updating the pool of evidence, health-care decision making and policy development (Roberts et al., 2002). The difficulty in integrating qualitative evidence in a meta-analysis lies in the lack of capacity of the traditional frequentist methods to evaluate qualitative evidence. It is hazardous and is not recommended to quantify any qualitative evidence (Giacomini 2001). Yet, in research on healthcare or treatment development, as recommended by Spiegelhalter (2004), the beliefs of all stakeholders should be included in the decision making. This includes subjective beliefs about the utility of the treatment, the credibility, the relevance, and implementation issues that are concealed in the "objective" evaluations, but apparent to clinicians and patients. These may jeopardise the effectiveness of otherwise efficacious intervention. The qualitative research provides rich data that cannot be easily utilised in decision-making as formal evaluation pf such evidence cannot be achieved by a narrative review alone (Roberts et al., 2002). It is also highly recommended to account for the needs of stakeholders – people living with HF in this thesis – in research concerning intervention development (Yardley et al., 2017). Bayesian methods provide an opportunity to integrate the qualitative evidence in making predictions about physical activity.

Degrees of belief about the probability of an event or an outcome are integrated into a Bayesian prediction model in the form of a prior distribution (Savage, 1951). Bayesian methods interpret prior distribution as an initial belief. Bayesian updating is the process by which the prior changes upon consideration of new evidence. The result is a new probability distribution representing the updated belief. It is called posterior probability distribution (Spiegelhalter et al., 2004).

In a Bayesian meta-analysis (Roberts et al., 2002) qualitative evidence was appraised by experts and described as a formal prior. This method is called expert prior elicitation task (Spiegelhalter et al., 2001). The idea is to determine a probability distribution that is consistent with a belief shared by a panel of experts (Spiegelhalter et al., 2001). Expert elicitation is often challenging and requires the design of a task that suits the phenomenon under investigation (i.e. the class of the probability mode (continuous vs binary, Gaussian vs Bernoulli probability distribution). It also must accurately describe the distribution to avoid shortcomings of performing any cognitive tasks (i.e. cognitive biases, bounded rationality and reasoning in humans. Roberts et al., (2002) in a study of vaccination uptake elicited a prior from experts' beliefs after they appraised the qualitative evidence. They then updated the prior with quantitative evidence. The resulting posterior probabilities represented predictions for the probability of vaccination uptake conditioned on each factor (Roberts et al., 2002). They found that lay beliefs about immunisation had the highest posterior probability of influencing vaccination uptake and thus were ranked above advice from health professionals, child's health, and logistics of travelling to receive the vaccine. Roberts et al (2002) were able to combine quantitative and qualitative evidence through Bayesian updating. The present meta-analysis is inspired by the work and methods used by Roberts et al. (2002).

However, this meta-analysis faces an additional challenge. There is prior evidence that physical activity is low in HF relative to the general population (Jaarsma et al., 2013). The predictive value for the probability of physical activity conditioned on a barrier or an enabler should be relative to the low probability of physical activity in HF in general. Thus, in this meta-analysis, Bayesian updating was performed twice. First, a "hyperprior" belief about physical activity in the general HF population was updated with qualitative evidence obtained by elicitation from experts. The resulting posterior distribution was then used as the prior for the second step, incorporating evidence from the reviewed quantitative studies. In a separate procedure the hyperprior obtained from Jaarsma (2013) was updated with quantitative evidence only. This was done to compare the evidence obtained from these two different sources.

Overall, Bayesian meta-analysis has three crucial advantages in reasoning about and inferring the barriers and enablers to physical activity in HF. (1) It ensures that the predictive distributions for each barrier or enabler are situated in the context of physical activity in HF. (2) It facilitates comparison of the barriers and enablers. (3) It allows integration of all relevant evidence despite inconsistency in epistemological stance or research design adopted in the evidence generation process.

5.3 Aim

The aim of this review is to systematically integrate qualitative and quantitative evidence concerning the clinical, environmental and psychosocial barriers and enablers influencing physical activity in HF.

5.4 Objectives

- systematically explore the evidence-base on barriers and enablers of physical activity in HF including qualitative and quantitative studies;
- identify, describe and compare clinical, demographic, psychosocial barriers and enablers to physical activity in HF

5.5 Research questions

- What are the barriers and enablers to physical activity in HF?

5.6 Methods

The meta-analysis was implemented and reported adhering to the Meta-analysis of Observational Studies in Epidemiology guidelines (Dekkers et al., 2019; Stroup et al., 2000). COSMOS-E (Dekkers et al., 2019), Cochrane handbook, and GDARE were consulted in planning the statistical analysis and the risk of bias evaluation.

5.6.1 Eligibility criteria

The phenomena of interest for this review were any clinical environmental, social or psychological barriers and enablers (Phenomenon of Interest) to physical activity (Evaluation/Outcome) that adults diagnosed with HF (Population) may face. The inclusion criteria were described in SPIDER and PI(E)COS format, for qualitative and quantitative studies respectively, and are presented in Table 5.1 .

The scope of interest for this review is large: barriers and enablers of physical activity in HF. Therefore, Design and Research type are unrestricted. The RCTs, however, are not included in this review as they are separately reviewed in Chapter 4.

Table 5.1. The scope of the review: PI(E)COS and SPiDER.

Qualitative study	Quantitative study
Sample: Adults diagnosed with chronic HF	**P**opulation: Adults diagnosed with chronic HF
Phenomenon of **i**nterest: Any beliefs or personal accounts on what clinical, environmental or psychosocial aspects of living with HF hinder or enable physical activity.	**I**ntervention/Exposure: **A**ny clinical, environmental or psychosocial variable, formulated as a correlate/predictor of physical activity in HF;
Design: Semi-structured interviews, focus groups, think-aloud studies; narrative reviews of qualitative studies.	**C**ontrol group: For dichotomous variables of exposure, the comparator group is the group of individuals living with HF **not** presenting with the clinical, environmental or psychosocial variable (e.g. lack of comorbidity). NA for continuous variables.
Evaluation: Physical activity, defined as any bodily movement that requires metabolic energy expenditure (WHO, 2010).	**O**utcome: Physical activity, defined as any bodily movement that requires metabolic energy expenditure (WHO, 2010), of any mode (e.g. walking); any intensity (e.g. MVPA); in any setting (as exercise prescription or otherwise).
Research type: Any qualitative methods (e.g. Phenomenological, ethnographic, or ground theory research studies)	**T**ype of study design: Cohort studies, cross-sectional observational studies, case-control studies.

5.6.2 Information sources

A total of 14 online databases were searched from inception to 05 January 2020 (Embase, Global Health, HMIC Health Management Information Consortium, MEDLINE; PsychINFO; CINAHL; Health policy reference centre; PsychARITCLES; PubMed; The Cochrane Library; Academic search complete, Pedro). The reference lists of the obtained articles included at full-text screening were hand searched for relevant studies meeting the inclusion criteria. ClinicalTrial.gov was searched for observational studies but yielded no results.

5.6.3 Search strategy

The terms describing the Population of interest (i.e. HF and nine synonyms combined using a Boolean operator 'OR') and terms describing the Outcome of interest (i.e. physical activity and 21 synonyms combined using a Boolean operator 'OR') were combined using a Boolean operator 'AND'. The searches were run across all article fields. The search strategy is identical to the terms describing 'Population' and 'Outcome' components for the meta-analysis of RCTs. However, the 'Intervention' and 'Control' components were omitted for this review. The search yielded a high number of hits (11,678) due to the lack of restriction on the Intervention/Exposure search component within PIECOT. The 'Exposure' component could not be restricted due to the research question. For practical reasons the search was restricted to articles that were peer-reviewed and written in English, respectively.

5.6.4 Study selection

The studies meeting the eligibility criteria (Table 5.1) were included in the review. The narrative review included qualitative and quantitative studies. A pairwise meta-analysis combined quantitative findings on physical activity per construct. The qualitative studies' findings were presented in the form of an informative prior elicited from the expert panel. A Bayesian meta-analysis combined the informative prior and the results of the quantitative studies.

5.6.5 Data collection process and data items

The details of interest were extracted using a data extraction form that was piloted on one cohort study and one qualitative study. The Strengthening the Reporting of Observational Studies in Epidemiology items list (STROBE; (von Elm et al., 2007) was utilised in the design of the data extraction form. The Consolidated Criteria for Reporting Qualitative Research (COREQ; Tang et al., 2017) recommendations for the qualitative studies item list were implemented as an ad hoc to the data extraction sheet for the qualitative studies.

The findings of the quantitative studies were tabulated in the following format: baseline physical activity levels, numbers of events (exercise compliant vs exercise non-compliant). For cohort and cross-sectional studies assessing continuous variables the mean and standard deviation (SD), and the association statistic (r, rho, beta coefficients, unadjusted estimates, and, if applicable, confounder-adjusted estimates and their precision: 95% confidence interval); the list of confounds that the summary statistic was adjusted for as well as the reasons for including this confound was extracted. When categorised/dichotomised physical activity outcome or the determinant were reported, the category boundaries were detailed accordingly.

5.6.6 Risk of bias in individual studies

Risk of bias was systematically described at study-level. The biases introduced by research design, methods, implementation, as well as confounds that may have contributed to the findings of the individual quantitative studies were considered. This included the following sources of biases: selective reporting bias, participant selection bias, missing data bias (including non-respondents and dropouts), confounding bias (measured and unmeasured confounds; time-varying confounds in cohort studies), outcome definition and measurement biases described as information bias (Dekkers et al., 2019) as recommended by (Page, McKenzie, & Higgins, 2018) and (Dekkers et al., 2019).

Due to the lack of a comprehensive risk of bias tool designed for observational studies (Page et al. 2018), three tools were used jointly: the Appraisal tool for Cross-Sectional Studies (AXIS), Working Group Item Bank (WGIB), and Risk Of Bias In Non-randomised Studies - of Interventions (ROBIN-I; (Page et al., 2018; Sanderson, Tatt, & Higgins, 2007; Viswanathan, Berkman, Dryden, & Hartling, 2013). These tools together provide a comprehensive reporting of the sources of biases as detailed in Table 5.2 . The ROBIN-I item concerning the randomisation procedure was omitted, an "intervention" was substituted with "exposure".

The quality of the included qualitative research was appraised being guided by COREQ based on the recommendations made by Majid & Vanstone (2018). COREQ was chosen because it was developed having systematic consideration in mind. Other existing tools developed for the appraisal of qualitative research (see review in Majid & Vanstone, 2018) were not suited for the following two reasons. Some alternative tools were not applicable because they were designed to inform clinical decision making (e.g. CASP) and are, therefore, too brief and do not provide an insight into biases that may arise from methods being used. While others were concerned with underlying philosophy (e.g. constructivism) and therefore were not suitable for the present review. Since this study is positivist and pragmatic in its epistemological stance, It is only concerned with identifying perceived barriers and enablers without regard for ontological differences.

Table 5.2. Tools used for the risk of bias assessment

Bias domain	*Question to consider*
Selection bias	*'Was selection into the study unrelated to both the exposure and outcomes?'* (Dekker et al. 2019 p.4). ROBIN-I
	'Were the reasons for missing data unrelated to the exposure and outcomes?' (Dekker et al. 2019). ROBIN-I
	'Were the controls sampled from the population that gave rise to the cases?' (Dekker et al. 2019). WGIB; AXIS.
Missing data bias	*'Were the reasons for the missing data related to the predictor being assessed?'* (Dekker et al. 2019). ROBIN-I; AXIS; WGIB
	'Were the reasons for missing data related to case/exposure status?'[1] (Dekker et al. 2019). ROBIN-I
Confounding **Time-varying confounding (if applicable)**	'*What are the important variables that might confound the effect of the exposure?*'(Dekker et al. 2019, p4). Included in ROBIN-I, WGIB, AXIS Is there evidence that controlling for this variable was unnecessary? (ROBIN-I)
	We're confounding variables measured at appropriate points in time. (Dekker et al. 2019). Included in ROBIN-I
	Did the authors use an appropriate analysis method or design that adjusted for all of the important confounding variables? (Dekker et al. 2019 p4). Included in ROBIN-I *Was the confounding variable measured using appropriate measurement?* (ROBIN-I) *Were time-varying confounding variables assessed?*[6] (ROBIN-I) *Was the follow-up/time lag appropriate (and balanced across groups*[1]*)?* (WGIB) *Any attempt to balance the allocation between the groups or match groups (e.g., through stratification, matching, propensity score?*[7] (WGIB)
Information bias/Measurement bias	*'Were outcome assessors unaware of the exposure status of study participants?'* (Dekker et al. 2019). ROBIN-I; AXIS; WGIB
	Were the methods of outcome assessment comparable across exposure groups? (Dekker et al. 2019). ROBIN-I.
	'Was the definition of case status applied without knowledge of exposure status?' (Dekker et al. 2019). ROBIN-I
	'Was data collection on exposure status unaffected by knowledge of the outcome or risk of the outcome?'(Dekker et al. 2019; and ROBIN-I)
Results summary bias/Statistical analysis	Was the sample size justified? (AXIS) Were results adequately described? (AXIS; WGIB) Were the precision and significance estimates clear (AXIS; WGIB) Were results internally consistent (AXIS; WGIB)?
Selective reporting	Were all outcomes reported? Is there evidence that not all outcomes were reported (ROBIN-I; AXIS; WGIB)

[6] Cohort studies

[7] Case-control studies

5.6.7 Synthesis of findings

5.6.7.1 Synthesis of the findings using the Theoretical Domains Framework

The result sections of the qualitative studies were coded line-by-line using the Theoretical Domains Framework (TDF) independently by three reviewers (the author of the thesis: AA, AC, BV). The descriptions of the important influences on physical activity in HF provided by the authors were coded into the domains and will be referred to as '*parses*'. The primary participant quotes included in the review were also coded. A domain was listed as relevant if it was mentioned to influence the behaviour at least once. The strength of the explanatory role of each domain in physical activity behaviour was judged from the normative phrasing and language used by the authors of the included papers in narrating qualitative summaries of the results. If coders perceived that parse could be classified as more than one domain, it was classified as all relevant domains. The coding agreement was high (AA vs AC: 87%); AA vs BV: 76%; BV vs AC: 86%.

Each parse was reduced to a shorter description of the barriers and enablers to physical activity in HF. These parses were compared to the definitions of a variety of psychosocial constructs. The reviewer (AA) was guided by the TDF list of constructs and the APA dictionary in this assessment. Also, common clinical terms (comorbidity, functioning) were utilised. The list of constructs produced from this content analysis was then mapped onto the exact description of the factors under investigation across the included quantitative studies. The precise definitions and constructs were used for quantitative analysis.

5.6.7.2 Summary measures

Standardised mean differences (*SMD*) were estimated to describe the impact of exposure on the levels of physical activity as follows (a) cross-sectional assessment of the differences in a between the group presenting with a characteristic and the group not presenting with a characteristic (e.g. female = 1; male = 0); (b) pre- post-assessment of physical activity in a cohort study before and after an event of interest (e.g. *SMD* between physical activity outcome before CRT and after CRT); cross-sectional assessment of differences between exercise compliant and non-compliant participants on a range of continuous variables (e.g. *SMD* in self-efficacy between compilers and non-compliers). The cut-off points used to define exercise compliance were noted for each study. In studies reporting categorical variables, the between the two upper bound categories and one lower bound category was used as an effect size estimate and integrated into pairwise meta-analysis. The *r-z* transformation was applied in the pairwise meta-analysis of coefficients to mitigate heterogeneity in measurements across studies. The Hartung-Knapp (Sidik-Jonkman) adjustment was made for the evaluation to mitigate small sample size bias (van Aert & Jackson, 2019).

For the Bayesian meta-analysis, the maximum a posteriori probability (*MAP*) estimate, and *credible Intervals* were calculated as a summary statistic for the probability distribution of physical activity conditioned on each determinant, Pr(PA|X).

5.6.7.3 Statistical analysis

Methods developed for conducting Bayesian meta-analysis (Spiegelhalter, Abrams, & Myles, 2003) were used to assess the associations between physical activity in HF and a total of 37 identified clinical, demographic, and psychosocial characteristics. This included: Pairwise meta-analysis, Expert elicitation task, and Bayesian updating. To obtain the probability of physical activity conditioned on a construct identified in the literature, Bayesian updating was performed as follows. First, the hyperprior described in Jaarsma (2013) was updated with the distribution elicited from experts after appraising qualitative evidence. Second, the resulting distribution was updated with quantitative evidence (Procedure II below). When only qualitative evidence was present only the first step was completed (Procedure I). When a construct was assessed in quantitative studies only, the second step omitting the first step was performed (Procedure III).

Hyperprior	Prior	Likelihood	Posterior
I. $Pr(PA \mid HF)$ →	→	→	$Pr(PA \mid HF, X_{qualitative})$
II. $Pr(PA \mid HF)$ →	$Pr(PA \mid HF, X_{qualitative})$ →	$Pr(PA \mid HF, X_{quantitative})$ →	$Pr(PA \mid HF, X_{all\ evidence})$
III. $Pr(PA \mid HF)$ →	→	$Pr(PA \mid HF, X_{quantitative})$ →	$Pr(PA \mid HF, X_{quantitative})$

5.6.7.3.1 Pairwise meta-analysis

The association between physical activity and factors assessed in quantitative studies were summarised in pairwise meta-analysis using a random-effect model with maximum likelihood estimation (REML). The bivariate correlation (Pearson's *r* coefficient, unadjusted) between physical activity and an associated variable and the standardised mean differences (*SMD*) between groups in dichotomised assessment were summarised in a pooled estimate, separately. The meta-analyses were implemented in **R** using the `metafor` library (Viechtbauer, 2010). To facilitate pooling of the estimates across studies employing heterogeneous measurement methods, two standardisation procedures were applied. The sampling distribution variance was standardised using an *r*-*z* transformation. This was done to mitigate heterogeneity in measurement of the outcome. *SMD* between exposure and control was estimated for the same reason.

5.6.7.3.2 Empirical hyperprior

A hyperprior was obtained from the secondary analysis of studies across 15 countries reported by Jaarsma et al. (2013). The total sample comprised 7625 adults diagnosed with HF (Appendix J). Empirical counts (N_{PA}) of people who engage in physical activity more than never, rarely or only sometimes was reported for each country (Jaarsma et al., 2013). A *Beta distribution* (with *æ* and *ß* shape parameters) was obtained as its conjugate prior distribution following the methods described by Spiegelhalter et al. (2003). The shape parameters *æ* and *ß* are estimated to be 5.43 and 7.19, respectively. The *MAP* was estimated to be 0.32, *Credible*

Interval = [0.2; 0.66]. This probability distribution was described as the hyperprior for the subsequent steps in the Bayesian updating.

5.6.7.3.3 Expert elicitation task

Second, the prior beta distribution was elicited from the qualitative evidence using expert elicitation task (i.e. informative prior). The experts included one professor of health psychology with extensive expertise in physical activity research; one lecturer of health psychology to medical students, with expertise in research on psychosocial outcomes in cardiovascular disease; three health psychology PhD students with experience in TDF qualitative research in the context of health and health care implementation (including the author of the thesis), and one Clinical Health Psychology Doctorate Trainee specialising in physical activity. The experts were asked to appraise the qualitative evidence and share their belief about the probability of physical activity under 30 scenarios. The scenarios illustrated hypothetical HF patients. The 30 hypothetical HF patients were described to either display a construct or not in three sets of combinations of the constructs identified in qualitative studies (Appendix K).

5.6.7.3.4 Bayesian updating

The likelihood (*log Odds Ratio*) of physical activity in the presence of a construct was obtained from the included quantitative studies (n = 24). From the pooled *log OR*, the empirical counts of physical activity conditioned on a construct (i.e. the number of physically active individuals who display a construct, for example physically active individuals with comorbidity, denoted as $N_{PA|X}$) were estimated using Markov chain Monte Carlo (MCMC) stochastic approximation with rejection sampling. Then, using stochastic methods of approximation, i.e. MCMC with Gibbs sampling, the parameters for the binomial probability distribution for physical activity conditioned on a construct – $Pr(PA|\,X)$ – were obtained from the sampled $N_{PA|X}$ in an **R** function.

The results were based on 50 000 iterations produced after the initial period of another 50 000 iterations. This was sufficient to achieve convergence. The convergence diagnostics were performed on the 50 000 monitored iterations. For the Markov chain Monte Carlo with a single chain, convergence was assessed graphically with trace plots (Appendix D). The convergence was assessed using Brooks–Gelman–Rubin statistic (Brooks and Gelman, 1998).

As the final fourth step, the posterior beta distribution was obtained by updating the prior with the likelihood for each construct separately using Bayesian updating. The methods detailed by Spiegelhalter et al. (2003, p.60) were implemented as follows:

$$Posterior = Beta(\alpha + N_{PA=1;X=1}; \beta + N - N_{PA=1;X=1}),$$

where the posterior probability distribution for physical activity conditioned on the construct is a beta distribution with two parameters:

$$\alpha + N_{PA=1;X=1}$$
$$ß + \mathrm{N} - N_{PA=1;X=1}$$

5.7 Results

5.7.1 Search results

The search results and the reasons for the study exclusion are summarised in Figure 5.1(PRISMA; Panic et al., 2013). A total of 9027 titles and abstracts and 82 full-text articles were screened.

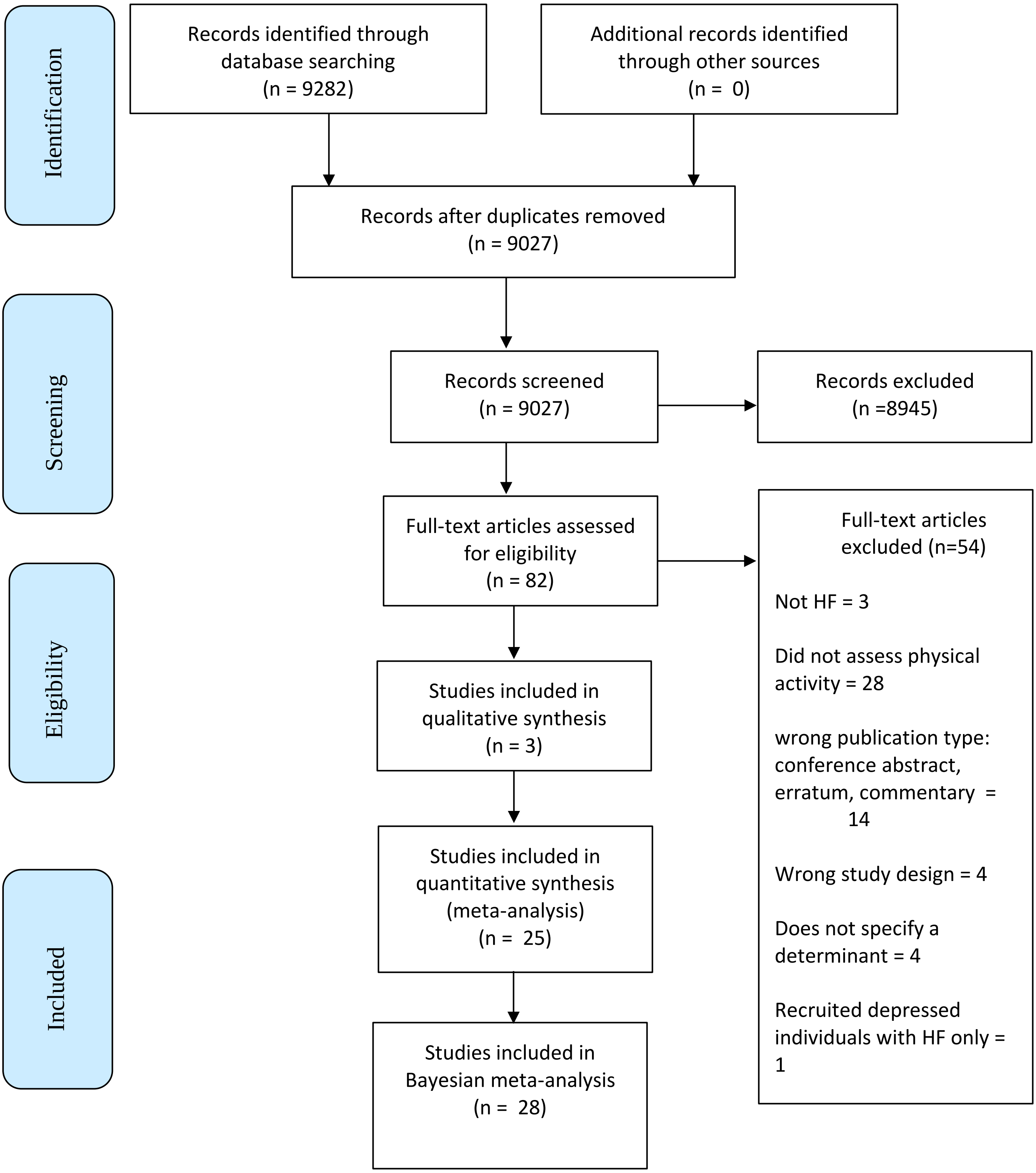

Figure 5.1. Meta-analysis of barriers and enablers of physical activity in HF: PRISMA diagram

The studies were excluded for the following reasons: a HF sample was not included (n = 3); physical activity levels were not assessed – the physical activity was not mentioned in a qualitative study – (n = 28); publication type did not satisfy the inclusion criteria (n = 14); and no particular clinical, demographic, environmental or psychosocial characteristic or a construct of interest was postulated/proposed as a predictor of physical activity in a quantitative study or identified as an important aspect of living with HF shaping physical activity behaviour in a qualitative study (n = 4). A total of four systematic reviews assessing *exercise capacity* outcome in HF that did not include a behavioural outcome were identified during search (n = 4).

Three qualitative studies were synthesised narratively; and 24 studies were synthesised in a quantitative analysis. Quantitative analysis consisted of multiple pairwise meta-analyses of univariate relationship between each variable and physical activity. A total of 27 studies were included in the Bayesian meta-analysis.

5.7.2 Characteristics of the included studies

5.7.2.1 Study design

A total of 28 were summarised in a narrative analysis. Ten studies were conducted in the United States of America; nine in Europe; three in the UK; two in Australia; one in Canada, one in South Korea, one in Taiwan. The majority of the included studies were of **a cross-sectional design (n = 16)** (Klompstra et al. 2018; Alosco et al. 2012; Evangelista et al. 2001; Gallagher et al., 2011; Garet et al. 2005; González et al. 2004; Haedtke et al. 2017; Jaarsma et al. 2000; Klompstra et al. 2015; Dontje et al. 2014; Lee et al. 2016; Oka et al. 1996; Pozehl, Mcguire, et al. 2018; Snipelisky et al. 2017; van der Wal et al. 2006; van der Wal et al. 2010; Witham et al. 2006). This included the baseline assessment from six RCTs.

One study (n=1) (Ho, Caughey, & Shakib, 2014) included a retrospective evaluation of physical activity and its association with clinical and demographic characteristics extracted from a clinical audit. The remaining were:

1. **cohort studies, n=6** (Andreae, Årestedt, Evangelista, & Strömberg, 2019; Chien, Chen, Garet, & Wang, 2014; Corvera-Tindel, Doering, Gomez, et al., 2004; Gad et al., 2018; Kramer, Jones, Rogers, Mitchell, & Reynolds, 2017; Werhahn et al., 2019);

2. **case-controlled, n=2** (Evangelista et al., 2003; Moreno-Suarez, Liew, Dembo, Larbalestier, & Maiorana, 2020);

3. **empirical qualitative studies, n=2** (Pihl, Fridlund, & Mårtensson, 2011; Tierney, Elwers, et al., 2011);

4. **and a narrative review**, n=1(Tierney, Mamas, et al., 2011).

The qualitative studies adopted phenomenological and semi-structured interview methods. One identified systematic review focused on sparse summaries about physical activity from the studies that elucidated beliefs and personal accounts of living with HF in general including physical activity only as one of many themes. It was chosen to include the review in this synthesis because it provides all available qualitative data prior to the first two qualitative studies that focused on physical activity in HF specifically.

5.7.2.2 Sample characteristics

The average sample size for quantitative and empirical qualitative studies were 110 and 17, respectively. One of the studies (Kramer et al., 2017) included 26,509 participants in a cohort study evaluating the effects of a prescribed implantable device. This study therefore constitutes 85.73% of the total sample included in this review.

All studies recruited (a) stable adult individuals with HF within various NYHA classes, (b) receiving outpatient care, (c) without a clinical diagnosis or clinical recommendation that impedes physical activity engagement. One study recruited and administered the baseline questionnaire to inpatient HF followed the cohort three months from discharge and conducted the second time point assessment in the outpatient settings. Only one study purposefully recruited adults older than 70 years (Witham et al., 2006). Haedtke et al. (2017) recruited clinically depressed HF patients. Three studies recruited – newly diagnosed (Werhahn et al., 2019), diagnosed for at least a year (Evangelista et al., 2003) or 23 months (Oka et al., 1996).

One study recruited HFpEF patients only, who also attributed inactivity to HF-related symptoms as assessed using an unspecified screening questionnaire (Snipelisky, 2017).

5.7.2.3 Physical activity assessment

Physical activity was assessed pre- and post-exposure to a predefined studied predictor (n = 2); overtime (n = 4); cross-sectionally (n = 17; including cross-sectional baseline assessment within an RCT, n = 6) and retrospectively (n = 1).

Physical activity outcome was measured as total triaxial movement (accelerometry units; n =3); total steps a day (n =5), energy expenditure (METs; categorised: n =1; summarised as a daily average (n=3); over seven days: n =9) time spent exercising (in hours: n=1; or minutes: n =4) or time spent sedentary (n=1). Two studies employed International Physical Activity Questionnaire (n=2; Craig et al., 2003). The total steps/day were categorised into moderate physical activity, low physical activity, and high physical activity levels. Likewise, energy expenditure was classified as: high, low, moderate. Binary compliance with a prescribed physical activity was assessed in two studies (n=6) and compliance rate was assessed in two studies (n=2). The pairwise meta-analysis was stratified by the physical activity outcome. Association between reported physical activity outcome and a construct was pooled after *r*-*z* transformation was performed (5.6.7.3) .

Table 5.3. Study Characteristics.

Author, year	Country	Study design	Study aims/objectives	Additional inclusion criteria	Sample size	The summary of the main findings
Alosco et al., 2012	USA	A cross-sectional study	To examine the role of depression in physical activity in HF as assessed using accelerometers. To determine if low physical activity is associated with death and hospitalisation.	Age: 50-85 years old; NYHA class: II and III; without any history of serious neurological disease, injury, sleep apnoea, renal failure and substance abuse	96	The number of years of education was significantly associated with a greater number of steps (b = 0.21, p<0.05) in a simple linear regression. Age, gender, and comorbidities were not identified as significant individual predictors of step count. When adjusted for comorbidity, age was identified a significant predictor of the daily step count. Comorbidities were not suggested to be associated with the outcome, when adjusting for age, gender and education. When adjusting for age, gender, comorbidities and education, the increased depression (BDI-II) was associated with the decreased daily count.
Andreae et al., 2019	Sweden	A prospective observational study	To assess the relationship between physical activity, functional capacity and appetite in HF.	Adults within NYHA class: II-IV, without kidney disease, dialysis, or short life expectancy due to cancer	186	The high levels of appetite were significantly associated with high levels of total energy expenditure (b=0.150, p=0.041), active energy expenditure (b=0.175, p=0.017), number of steps (b=0.254, p<0.001), METs daily average (b=0.199, p=0.007).

Chien et al., 2014	Taiwan	A prospective observational study	To explore physical activity predictors (as assessed at discharge) one month after discharge.	75 years old or younger ; NYHA class: I-III.	111	19.12% of daily energy expenditure (DEE) was within low intensity (<three METs), 7.20% within high (3-5 METs), and only 1.42% was intensive (>five METs). BMI, age, self-efficacy for instrumental activities of daily living, and educational level were predictors of total DEE one month after discharge. Self-efficacy for instrumental activities of daily living, gender, and BMI were predictors of high DEE. Age, BMI, and symptom distress were predictors of intensive DEE.
Corvera-Tindel et al., 2014b	USA	A prospective observational study	To evaluate clinical and psychosocial characteristics among exercise complaint and non-compliant HF patients.	-	39	Compliance with recommendation to walk weekly was associated with higher HF duration, higher comorbidity, lower BMI, and lower hostility
Dontje et al., 2014	Netherlands	A cross-sectional study		NYHA class: I and III; with 1-year survival prognosis; without any implantable devices; who have not undergone any surgical interventions; without AF and arrhythmia; without a recent embolism.	68	Sig. difference in steps/day between patients within NYHA I-II (median=6113) and patients within NYHA III (median= 3150) ($p<0.001$); between patients with EF ≤40 (median= 5854) and patients with EF >40(median=3246) ($p<0.05$); no significant difference in steps/day between men and women ($p=0.389$). Steps/day was only significantly correlated to age (Spearman's rho=-.43) and self-efficacy (Spearman's rho=.40), but not to other characteristics. NYHA classification, EF, age, and self-efficacy explained 42% of the variance in steps/day ($F=8.69$; $p<0.001$) in linear regression model.

Evangelista et al., 2001	USA	A cross-sectional study	To identify precipitating factors of self-care non-compliance.	-	82	Significant correlates of exercise compliance included higher physical (r =0.507) and mental health (r =0.468) and health satisfaction (r = 0.435) lower neuroticism scores (r =–0.317).Age, race, education, and marital status were not sig. associated with physical activity levels.
Evangelista et al., 2003	USA	A case-controlled study well-matched (younger<70; vs older>70)	to describe physical activity differences in older (>70 years old) and younger (<70) individuals diagnosed with HF	Diagnosis duration for over a year	140	The mean compliance score was significantly different between older (>70 y. old) and younger (<70 y. old) adults, 67.14 ± 32.28 and 55.00 ± 29.05, respectively, p= 0.021.
Gad et al., 2018	Canada	A prospective observational study	To evaluate Cardiac Resynchronisation Therapy (CRT)	Patient older than 50 years old scheduled to receive CRT (in hospital)	25	The steps/day decreased from baseline (405 ± 2334) to post-CRT (2553 ± 1692). No sig. change was observed in other physical activity modes.
Garet et al., 2005	France	A cross-sectional study	to evaluate the influence of daily physical activity on established HRV prognostic indices in patients with varying severity of CHF.	Nr	39	The difference in duration of physical activity (measured in minutes/week and energy expenditure (PAEE: 871.3 +79.5; PA low: 683.7+139.8; PA high: 152:0+105.4; PA intensive: 3.2+8.2) across NYHA classes was non-significant

Gallagher et al., 2011	USA	RCT; only the results of the baseline assessment were included in this review	To determine the types and level of social support in HF provided by partners; to evaluate the impact of the partner's social support levels on self-care behaviours in comparison to individual without partners on HF.	Not scheduled for or underwent any surgical interventions in the past 6 months	333	The extent of regular exercise ('I exercise regularly': 5-point Likert scale) between groups with low social support (no partner), medium, and high was significantly different, mean = 2.95 (SD=1.28), mean = 2.81 (SD=1.27), mean = 2.41 (SD=1.29), respectively. The authors concluded not having a partner did not significantly change physical activity levels in people with HF. However, the perception of low social support vs high social support did.
Gonzalez et al., 2004	Spain	A cross-sectional study			324	Younger patients, men and patients referred from the cardiology outpatient clinic performed more physical activities, compared to older patients, women and patients referred from other departments.
Haedtke et al., 2017[8]	USA	A cross-sectional study	To describe physical activity levels in depressed individuals diagnosed with HF; to describe the relationships	Age: >55 years old; Beck Depression Inventory Score >10; physical functioning score (RAND)< 70	61	NYHA class and age were not associated with total duration of physical activity. Age and NYHA class significantly predicted the time spent sitting. For every year increase in age, the odds of being the higher sitting time group increased by 18% controlling for NYHA class and total time spent exercising (see all). Participants who were in NYHA class III-IV had 20 times higher odds of being in the

[8] The study by Haedtke et al. (2017) was excluded from the meta-analysis because the study inclusion criteria listed diagnosis with depression.

			between pain, depression and physical activity			higher sitting time group than those in the NYHA class II.
Ho et al., 2014	Australia	A retrospective hospital clinical audit	To describe the role of common comorbid conditions (atrial fibrillation, ischemic heart disease and diabetes) and other demographic and clinical factors on the compliance with clinician's self-care advice.	Presence of multiple comorbidities (unspecified).	255	Participants compliant with the exercise recommendation were significantly different from non-compliant counterparts in their age (79 (71–84), enrolment in HF programmes, 33 (47%) vs 25 (20%) and Number of appointments (Median = 6 (IQR: 4-11) vs Median = 3 (IQR: 2-7)).
Jaarsma et al., 2000	Netherlands	RCT; only the results of the baseline assessment were included in this review	To evaluate the role of education and support on self-care behaviours in HF.	Not scheduled for or underwent any surgical interventions in the past 3 months and admitted to the hospital for the first time. NYHA class: III-IV; older than 50 years old.	128	A total of 59 (46%) participants did not follow exercise recommendations for HF patients. One listed the lack of *Knowledge*, six the lack of Decision (*Intention*), 37 the lack of *Skill* as the limitation to the behaviour. The remaining 15 stated that the limitation is 'not known'.

Klompstra et al., 2015[9]	Sweden	A cross-sectional study	To describe gender-specific barriers and enablers to physical activity in HF.	nr	154	The low level of the physical activity group (<3000 METs) had a higher number of participants who were educated to the primary school level only, than the high physical activity group (>3000 METs), 55% vs 36% respectively, p=004. Similarly, high level physical activity group were significantly more self-efficacious (mean score 2±1 vs 1.1) and motivated (mean score 4±2 vs 3±2) to exercise than the low-level physical activity group, p<0.01. No difference in proportion of male/female and NYHA class, as well as number of comorbidities were found between two physical activity groups.
Klompstra et al., 2018	Sweden	A cross-sectional study	To evaluate the mediating role of exercise self-efficacy on the relationship between motivation and physical activity.	With life expectancy not shorter than 6 months	100	Exercise motivation significantly predicted physical activity in a bivariate linear regression (b = 0.58, P = .02). . After controlling for exercise self-efficacy, the effect of exercise motivation on physical activity was zero (b = 0.76, P = .06). Authors concluded that self-efficacy fully mediated the effect of motivation on physical activity. Age (b = -0.03, P = .22), and NYHA class (b = -0.41, P = .46) did not predict the amount of physical activity
Kramer et al., 2017	USA	A prospective pre-post study	To describe the change overtime in physical activity after receiving a CRT	Recipients of CRT	26509	The average physical activity levels for the cohort was 66.2 (SD=47.7) min/day at baseline, 99.7(SD= 60.9 min/day) at short-term follow-up after the CRT (30-60 days), and 103.2+ 65.6 min/day at (180-210 days). 15.5% of patients did not improve or worsened at 6 months.

[9] Not included in the analysis due to lack of reported summary statistic

Lee et al., 2017	South Korea	A cross-sectional study	To describe the relationships between physical functioning, physical activity, exercise self-efficacy, and QOL in individuals with CHF.	-	116	Correlations between physical activity and self-efficacy, quality of life, age, income, education, and LVEF were assessed. Physical activity significantly and negatively correlated with age (r = -0.194, p<0.01)
Moreno-Soarez et al., 2020	Australia	A case-controlled study(well-matched patients with LVAD versus well-matched patients with CHF, but no LVAD)	to describe daily PA levels in patients with LVAD support compared with well-matched participants with advanced CHF without LVAD support.	Without hypertension	32	In a matched for age (±5 yr.), sex, and New York Heart Association (NYHA) class, cohort study, participants with a fitted LVAD had higher levels of energy expenditure than individuals with HF who were not fitted with the device, 404.1 ± 169.1 kcal/d ay and 222.5 ± 163.4 kcal/day, respectively.
Oka et al., 1996	USA	A cross-sectional study	To describe the relation between knowledge, attitudes and beliefs, and physical activity levels in patients with HF.	Diagnosis duration for at least 23 months; without obstructive valvular disease; congenital hear1 disease; and tachycardia pacemakers; severe pulmonary hypertension	43	The association between physical activity and physical fitness (peak VO2,); knowledge, attitudes, and beliefs including self-efficacy for general activity, and rating of perceived exertion during daily activity; and marital status) was assessed. Self-efficacy (p= 0.015) was the strongest predictor of physical activity.

Pihl et al., 2011	Sweden	Phenomeno logical analysis of qualitative interviews	To describe qualitatively how individuals with HF conceived their limitations in daily life activities.	Stratified recruitment strategy to obtain variation in the sample in terms of gender, age place of residence, education, and NYHA class.	15	The study supported the relevance of the following domains to physical activity in HF: *Knowledge*, *Social/Professional Role and Identity*, *Beliefs about Capabilities*, *Beliefs about Consequences*, *Goals* (low relevance), *Memory, attention and decision processes* (low relevance), *Social Influences*, *Emotion*, and *Behavioural Regulation*.
Pozehl et al. 2018	USA	RCT; only the results of the baseline assessment were included in this review	To describe physical activity levels (using accelerometry), operationalised as MVPA or EE; to determine the proportion meeting the recommended levels of physical activity; to describe factors associated with physical activity.	Coronary artery bypass surgery, or biventricula pacemaker less than 6 weeks prior; participation in 3 times per week aerobic exercise in the past 8 weeks; plans to move more than 50 miles from the exercise site within the next year; peak oxygen uptake (pVO2) in females > 2 ml/kg/min and in males > 24 ml/kg/min; and pregnancy planned or current.	204	The MVPA (mins/day) was significantly higher in males (than females $p < 0.01$), Caucasians than non-Caucasian ($p < 0.05$), those within NYHA class II compared to those within NYHA class III. The higher Charlson comorbidity index and PROMIS anxiety score was significantly associated with the higher level of MVPA. Ejection fraction was not significantly correlated with MVPA.
Snipelisky et al., 2017	USA	RCT; only the results of the baseline assessment were included in this review	To describe the relationships between daily activity with clinical features and standard HF assessments (NYHA class, 6MWD, HF QOL scores and NT-proBNP) at baseline	Patients were eligible for study participation if they had NYHA class II-IV least 50 years of age, had preserved (≥50%) EF who attributed	110	Participants in the group with the lower daily accelerometer units were more likely to have had HF hospitalization, orthopnea, diabetes and anemia, be treated with beta blockers, have higher EF, relative wall thickness and left atrial volume and worse NYHA class, HF specific quality of life (QOL) scores, six minute walk distance (6MWD) and NT-proBNP ($p<0.05$ for all).

			and the relationship between changes in activity and changes in standard HF assessments with ISMN relative to baseline (controlling for sex, age, and body size).	inactivity to HF related symptoms as assessed using a screening questionnaire.		
Tierney et al. 2011a	UK	A qualitative semi-structured interview study	To explore why individuals with HF do and do not engage in regular physical activity.	-	22	Changing Soma The reported beliefs were coded into the following domains: *Knowledge*, Social/Professional Role and Identity, Beliefs about Capabilities and Having realistic expectations about the future was coded into Beliefs about Consequences, Also, Mental outlook theme was coded as Optimism/Emotion (medium relevance), Goals (low relevance), Environmental context and resources, Social influences, Intention (low relevance).
Tierney et al., 2011b	UK	A narrative review of qualitative studies	To summarise the findings of interview studies on living with HF that concern beliefs about physical activity.	Qualitative studies (n=20) aiming to describe HF beliefs and accounts of living with HF	306 (average = 15)	The reported beliefs supported the relevance of the following domains: *Knowledge*, Social/professional role and identity, Beliefs about capabilities, Beliefs about Consequences, Goals (medium relevance), Environmental context and resources, Social influences, Emotion.
van der Wal et al., 2006; 2010	Netherlands	A cross-sectional study	To investigate the association between compliance with non-pharmacological recommendations	-	2006: 501 2010: 830	Participants who did not adhere to the exercise recommendation were older, more likely to be female and to have comorbid Atrial fibrillation, diabetes, stroke, and previous HF admission.

			(diet, fluid restriction, weighing, exercise) and outcome in patients with heart failure (HF).			Depressive symptoms and knowledge was negatively associated with compliance to exercise recommendation.
Werhahn et al., 2019	Germany	A prospective observational study evaluating an intervention; only the results of the baseline assessment were included in this review	To evaluate feasibility and usability of A mobile application designed to enhance self-management.	Newly diagnosed HF	10	Everyday physical activity (the MDSC captured by built-in pedometer functions of smartphone and smartwatch)averaged over 14 days was low following hospital discharge (3612 ± 3311), increased significantly to the first follow-up (6927 ± 4871; P < 0.0001) and to the end of study (7069 ± 5006; P < 0.0001) the MDSC correlated significantly with parameters of exercise capacity – the distance in the conventional 6MWT and peak VO2 in CPET. A strong association with patient-reported outcomes in the MLHFQ and KCCQ, especially with the sub-scores representing health-related QoL, HF symptoms, and PA, was observed.
Witham et al., 2006	UK	RCT; only the results of the baseline assessment were included in this review		Older adults (>70) without ventricular fibrillation, aortic stenosis with peak gradient >30 mm Hg, atrial fibrillation with ventricular rate of >10	82	Daily physical activity (accelerometer) was significantly associated with the 6-minute Walking Test (distance in meters).
Total number of studies: 28		16 cross-sectional (57%; five of which are baseline assessment from an RCT); 1 retrospective study; 6 cohort			**Total N: 30921**	

	studies; 2 case-controlled; 2 empirical qualitative studies; 1 narrative review	

5.7.3 Risk of bias identified across quantitative studies

The risk of bias is reported Figure 5.2. Participant selection bias was present in 8% of the included studies (n = 2; Garet et al., 2005; Klompastra et al., 2018). A total 12% reported high level of missing data (n = 3; Andreae et al., 2019; Klompstra et al., 2018; Haedke et al., 2017). The measurement bias caused by the dichotomisation of the age variable was present in 4% of the studies (n = 2; Gonzalez et al., 2004 and Evangelista et al., 2003). Three studies had high risk of reporting bias, as only positive results were reported (n = 3; Garet et al., 2005; Evangelista et al. 2003; Evangelista et al 2001). The justified adjustment for confounding variables was made in four studies (16% low risk of confounding bias).

5.7.3.1 Studies excluded from meta-analysis due to high risk of bias

Haedtke et al., (2017) purposefully recruited depressed individuals only and assessed correlates of physical activity such as age and NYHA class within this sample. Therefore, this study was excluded from the meta-analysis to avoid the confounding effect of depression on levels of physical activity. A summary of the findings is presented in Table 5.3

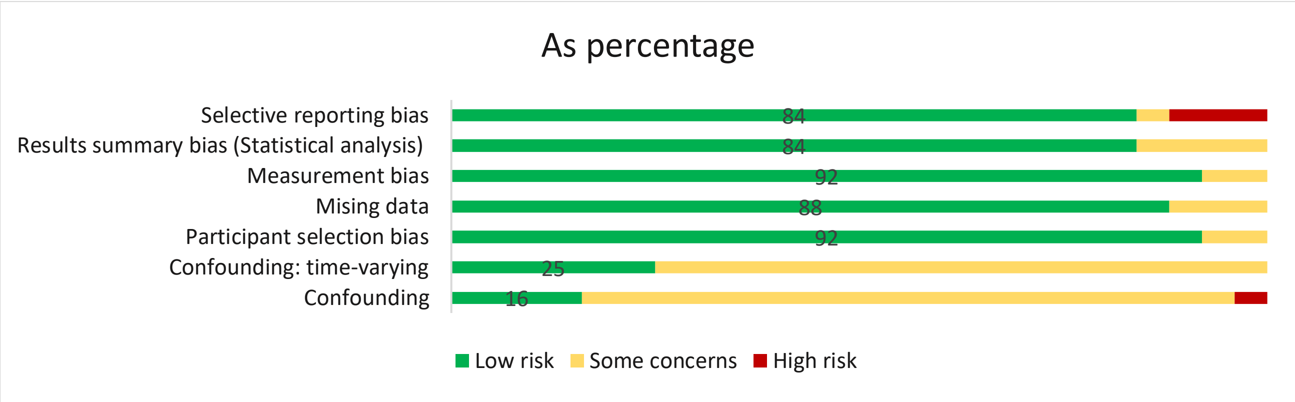

Figure 5.2. The overall risk of bias at study level: Based on WIB, ROBIN-I, and AXIS items combined into six categories proposed by Page et al., 2018 with an addition of the confounding bias described in ROBIN-I and a reflection on biases introduced while carrying out statistical analysis (WIB).

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Note: *time-varying confounding applicable to prospective studies; NA for Cross-sectional

	Confounding	Confounding: time-varying*	Participant selection bias	Mising data bias	Measurement bias	Results summary bias	Selective reporting bias
Alosco et al., 2012	?	+	+	+	+	+	+
Andreae et al., 2019	+	NA	+	?	+	+	+
Chien et al. 2014	?	?	+	+	+	+	+
Corvera-Tindel et. al., 2004	?	NA	+	+	+	+	+
Dontjie et al., 2014	?	NA	+	+	+	+	+
Evangelista et al., 2003	?	?	+	+	?	?	Ñ
Evangelista et al., 2001	?	?	+	+	+	?	Ñ
Gad et al., 2018	?	NA	+	+	+	+	+
Garet et al., 2005	?	NA	?	+	+	+	Ñ
Gallagher et al., 2011	?	NA	+	+	+	+	+
Gonzalez et al., 2004	?	NA	+	+	?	+	+
Haedtke et al., 2017	Ñ	NA	+	?	+	+	?
Ho et al., 2014	?	NA	+	+	+	+	+
Oka et al., 1996	+	NA	+	+	+	+	+
Jaarsma et al., 2000	?	NA	+	+	+	+	+
Klompstra et al., 2018	+	+	?	?	+	+	+
Kramer et al., 2017	?	?	+	+	+	+	+
Lee et al., 2017	?	NA	+	+	+	+	+
Moreno-Soarez et al., 2019	+	NA	+	+	+	+	+
Pozehl et al. 2018	?	?	+	+	+	+	+
Snipelisky et al., 2017	?	?	+	+	+	+	+
van der Wal et al., 2006; 2010	?	?	+	+	+	?	+
Werhahn et al., 2019	?	?	+	+	+	+	+
Witham et al., 2006	?	NA	+	+	+	?	+

Low risk +
Some concerns ?
High risk Ñ

Figure 5.3 The sources of risk of biases reported for individual studies.

5.7.4 Participant characteristics

The mean age of the participants of the included studies was 65.88 years (SD = 7.82, median = 67, IQR:[60.8;67]). Participants were diagnosed with HF for 5.34 years on average (median). The LVEF (Left Ventricular Ejection Fraction, %) was moderately low (mean = 34.82 %). Overall, the majority of samples of the included studies were homogeneous (n = 22). The sample characteristics for individual studies are reported in Appendix L.

Six studies included samples that were different to the rest of the studies. One of these samples was exceptionally young (mean age = 46.3) with a mean diagnosis duration of less than three months (Werhahn et al., 2019). Haedtke et al. (2017) recruited clinically depressed individuals only. An older sample (>70 years old) was included in four studies (Klompstra et al., 2018; Ho et al., 2014; , Andreae et al., 2019; and van der Wal et al., 2010).

5.7.5 Constructs identified across literature

Constructs that were identified as relevant in qualitative studies were: Outcome Expectancies, Self-identity/ social role, Social support (barrier), Social pressure, General social and environmental factors: Credible advice, Reassurance from a health professional that physical activity is safe, Local environment, Problem solving, Action planning, Pharmaceutical treatment.

The relevance of the following constructs were assessed in quantitative studies only: Ethnicity (non-Caucasian), Income (high), Education, being employed, Six-minute Walking Test (meters), HFpEF diagnosis, Peak V02, The Doppler Test, High levels of Pro BNP, Body Mass Index, Left Ventricular Ejection fraction (<40%), implantable devices (LVAD, LVR, and CRT), HF duration, living with a Partner (vs no Partner), QoL, Smoking, Depression, Dysphoria. These clinical and demographic characteristics were assessed in a pairwise meta-analysis.

Constructs such as age, comorbidity, social support, symptom severity, functioning, and self-efficacy, negative attitude and positive attitude toward physical activity were suggested to be relevant determinants of the behaviour in the qualitative studies and are also assessed in quantitative studies. Therefore, the association between these constructs and physical activity stratified by the outcome were assessed in Bayesians analysis.

5.7.6 Summary of qualitative evidence

The direct participant quotes and themes suggested by authors of the included studies were coded into TDF domains (Table 5.4). The qualitative findings from three studies (Tierney et al., 2011a, 2011b, Pihl et al. 2011) suggest a high relevance of the following domains: *Beliefs about Capabilities*, *Social Influences*, *Beliefs about Consequences*, *Social, Professional Role and Identity*, *Environmental Context and Resources*, *Behavioural Regulation*. In one study three domains were collectively listed under the umbrella term "External Factors". They were: *Environmental Context & Resources*, *Social Influences*, *Knowledge*.

Table 5.4. Barriers and enablers to physical activity in HF identified relevant by qualitative studies.

TDF domain	Constructs	Themes as identified by authors and exemplar quotes	
Barriers and enablers that were identified relevant by the qualitative evidence and were assessed in qualitative studies			
Beliefs about Capabilities	Age (years)	***Changing Soma*** *'Changing soma refers to a decline in physical and mental abilities, which many participants thought was related to aging. An altered body was perceived to be a natural part of getting older by some of those participating in reviewed studies, who mentioned feeling too old to amend their behaviours. But the body could also be experienced as failing'*(Tierney et al., 2011a) *'because of increasing age, the future itself would be marked by a change in physical functioning'(Tierney et al., 2011a). There were participants who perceived that their age and not only their chronic HF had an impact on their physical capacity*. (Tierney et al., 2011a) *These individuals seemed more adaptive to physical limitations, as they accepted them as a natural part of the process of ageing and were thus more likely to try to attempt activities and test their functions, as they did not consider strain on the heart a problem." (Pihl et al., 2011).*	Medium Barrier
Beliefs about Capabilities	Decline in Functioning/Functioning	***Not believing in one's own ability (***Decline in Functioning) *'There were participants that considered their limited physical capacity and need of support as a burden because they experienced that they inconvenienced the helpers, while others found it natural that friends and family members helped them: 'There's a lot that needs to be done. I make a list of things that I can't manage myself. For example, I can't carry a whole basket of laundry from the basement.// But my children take care of that when they come home.' (Tierney et al., 2011b)*	Medium Barrier
Beliefs about Capabilities	Comorbidity	***Changing Soma***	Medium Barrier

		'They hoped to return to being active but felt limited at present because of other conditions (e.g. arthritis) and/or HF symptoms (e.g. fatigue and breathlessness).' (Tierney et al., 2011a)	
Beliefs about Capabilities	Perceived symptoms	***Fluctuating health*** *'I'm breathless and tired, that's what I am, but I never think about that, I'm quite well. (Ekman, Ehnfors, & Norberg, 2000, p. 133)* *They hoped to return to being active but felt limited at present because of other conditions (e.g. arthritis) and/or HF symptoms (e.g. fatigue and breathlessness).'* (Tierney et al., 2011a)	Important Barrier
Beliefs about Capabilities	Self-efficacy[1]	***Not believing in one's own ability*** *'There were participants that considered their limited physical capacity and need of support as a burden because they experienced that they inconvenienced the helpers, while others found it natural that friends and family members helped them: 'There's a lot that needs to be done. I make a list of things that I can't manage myself. For example, I can't carry a whole basket of laundry from the basement.// But my children take care of that when they come home.'* (Tierney et al., 2011a)	Important Enabler
Social Influences	Social support (enabler)	***Interpersonal influence of family and others*** *'Exercising with others in these classes was said to help maintain motivation; several people enjoyed attending because they met peers who were ''in the same boat'' (Pt 12)' (Pihl et al., 2011).*	Important Enabler
Emotion/Optimism	Negative attitude	***Negative emotional response*** *'Negative emotional response (e.g., low mood, frustration) to changed physical status was described in several papers. Pessimistic reactions to physical changes could have a deleterious impact on willingness to exercise as a consequence. Not knowing when they would experience deterioration in health made certain patients feel helpless: . we don't go anywhere, we've got a wedding invitation and hope to God that things are a wee bit better so that we can go, just to get us out somewhere, you know. (Pattenden et al., 2007, p. 276)' (Tierney et al., 2011a)*	Important Barrier
Emotion/Optimism	Positive attitude	***Mental outlook*** *'[] patients expressed a more positive outlook; they tended to speak optimistically about the future (e.g. they mentioned getting on with life, receiving the best care possible); even though it may have been a shock at the time of diagnosis, the sense of fear described by those not undertaking regular exercise was missing from interviews…'*(Tierney et al., 2011a)	Important Enabler

Barriers and enablers that were identified relevant in qualitative studies but were not assessed in quantitative studies			
Beliefs about Consequences	Outcome Expectancies (positive)	***Having realistic expectations about the future*** *'Focus on the participants' expectations of their future life. Aspects derived: Assuming a need for change in daily life, striving to maintain the quality of daily life and continuously making progress in daily life.'* (Tierney et al., 2011a)	Important Enabler
Social professional Role and Identity	Self-identity/ social role	***Losing one's social role in daily life*** *'The participants described losing their social network as well as their position in society'*(Tierney et al., 2011b)	Important Barrier
Social Influences	Social support (barrier)	***Interpersonal influences of family and others*** *Interpersonal influences of family and others shaped activity levels. Physical limitations called for patients to accept help. This was difficult, seeing family members doing housework and not being able to assist as they wished Individuals could be left feeling dependent, which contributed to the frustration and low mood (Tierney et al., 2011b):*	Important Barrier
Social Influences	Social pressure	***Others' expectations*** *' Interactions with relatives and professionals could prompt or impede decisions to be active.'* (Tierney et al., 2011a)	Important Enabler
Environmental Context/Resource , Social Influences, Knowledge	General social and environmental factors: Credible advice, reassurance	***External factors*** *'Uncertainty was raised about how much exercise could be carried out safely. Some interviewees also wanted further advice about how to target parts of their body through exercise'*(Tierney et al., 2011a)	Important Enabler
Environmental Context and Resources	Local environment	***Environmental influences*** *'Participants generally felt more energetic when the spring came, While winter was reported to be a difficult season for them in this respect. Given that most people defined walking as their main form of exercise, weather could have a significant impact on behaviours; ice, rain and cold temperatures deterred them from undertaking this activity, as did very hot weather.'* (Tierney et al., 2011a)	Mixed

Behavioural Regulation	Problem solving Action planning	***Need of finding practical solutions in daily life*** *There's a lot that needs to be done. I make a list of things that I can't manage myself. For example, I can't carry a whole basket of laundry from the basement.// But my children take care of that when they come home.' (Tierney et al., 2011b)*	Important Enabler
Environmental Context and Resources	Pharmaceutical treatmen	***Pharmaceutical treatment*** *A well-managed unspecified pharmaceutical treatment was perceived to improve physical activity and listed as an important enabler (Tierney et al., 2011b)*	Important Enabler

5.7.6.1 Environmental Context and Resources

Environmental Context and Resources included environmental influences such as medication (unspecified), environment (e.g. garden), seasonal changes, hills/incline. The property of the environment defined whether it imposed a barrier or an enabler. Overall, medication caused side effects and led to a decline in activities. On another hand, well-managed pharmaceutical treatment (unspecified) promoted a physically active lifestyle. Having local environments such as gardens was an important enabler. Seasonal changes guided the seasonal fluctuation in physical activity. Participants reported to be more active during summer and spring and less so during winter.

5.7.6.2 Beliefs about Capabilities

Beliefs about Capabilities consisted of themes such as '*Changing soma*' and '*Self-efficacy'* or *'Not believing in one's ability'*. '*Changing soma'* included both reported physical functioning (due to age or otherwise) and perceived ability (self-efficacy). The former was categorised as either symptoms or general decline in functioning. Self-efficacy, being identified as a theme in its own right, was coded as an important enabler. Comorbidity, ageing, and functioning were components of the theme '*Changing soma'* or *'Not believing in one's ability'*, and therefore are described as medium barriers.

5.7.6.3 Knowledge

Knowledge domain comprised of a theme described by the authors as "*External factors*" whereabout the advice to engage in physical activity was or was not reiterated or clarified by the healthcare team.

5.7.6.4 ***Behavioural Regulation***

Behavioural Regulation included a theme such as "*Need of finding practical solutions in daily life*" as well as a direct quote which was coded within another theme, described as "*Changing soma'*, which referred to the decline in the ability to plan activities, associated with general decline in functioning: "*For example, unpredictability of symptoms made it hard to plan activities, with a lack of energy sometimes interfering with scheduled events.*

5.7.6.5 Beliefs about Consequences

The theme coded within *Beliefs about Consequences* was '*Fluctuating health' (Tierney et al 2011b)* and covered rapid onset and unpredictable course of symptom severity such as breathlessness and fatigue. This was coded as an important barrier. The *Beliefs about Consequences* included beliefs about the improvement in cardiac health: "*Some individuals re-evaluated life following diagnosis and became more active because they thought this was good for their heart." (Pihl et al. 2011).* In addition, avoidance of independence was another outcome expectancy associated with physical activity: '*You just have to struggle and get up . . . you have to practice that . . . because I know how things go if you get too dependent on your bed; people have to come in and help you more often.' (Pihl et al. 2011).*

5.7.6.6 Social Professional Role and Identity

Social Professional Role and Identity was described as a theme entitled: "Losing one's social role in daily life. The included description provided by the authors: 'A lack of important issues, mental as well as physical, occurred when they lost the physical capacity to perform activities of daily life.'

5.7.6.7 Social Influences

Social support (*Social Influences*) was of two kind. The first involved quotes describing significant others or family carrying out activities on the behalf of the participants which was coded as Social support (barrier). Social support (enabler) included quotes describing the provision of support that enabled individuals to engage in physical activity, such as emotional support and reassurance: *I have a friend, and we kind of team up and help each other stay on the straight and narrow. It's a lot easier when you have someone to share it with. (Pihl et al., 2011).* These were aggregated into *'Social and interpersonal influences'* theme and were coded as both an important barrier and an important enabler.

5.7.6.8 Emotion and Optimism

A theme '*Mental outlook*', coded as an important enabler, spanned across three domains and included: positive attitude toward physical activity (*Emotion*) and Optimistic beliefs (*Optimism*).

Similarly, coders agreed that the theme identified by the authors of included study: '*Negative emotional responses' can be described in terms of Emotion* domain (i.e. emotional response toward physical activity that impacted willingness to engage in physical activity) and Optimism ('*Not knowing when they would experience deterioration in health made certain patients feel helpless')*.

5.7.7 Frequentist pairwise meta-analysis results

In a meta-analysis including univariate associations (*r-z* coefficient, 95% CI), the following factors were significantly and negatively correlated with physical activity: age, comorbidity, depression, and HF-diagnosis duration (Table 5.5). Positive attitude toward physical activity, functioning, 6-minute walking test, perceived symptoms, and self-efficacy were significantly and positively correlated with physical activity (Table 5.5).

In a meta-analysis of differences (*SMD*, 95% CI), the following barriers to physical activity were identified: being employed, having undergone LAV surgery, perceiving higher social support in managing HF, and living with a partner (Table 5.5). Exercise compliant individuals with HF had significantly lower mean HF diagnosis duration (years), comorbidity score (Charlson Comorbidity Index, CCI), renal function, and significantly higher doppler estimated filling pressure, and Quality of Life (QoL score), (Table 5.5). PeakV02 was significantly different between exercise-compliant and non-compliant individuals living with HF, where exercise compliant individuals had a significantly larger mean PeakV02 than their counterparts. Individuals who had an LVAD implanted had significantly higher physical activity levels than those who did not have an LVAD (Table 5.5). The number of studies assessing the identified constructs, as well as the method of assessment of both physical activity and the construct, are reported in (Table 5.5).

Table 5.5. Summary of the quantitative evidence, probability of physical activity conditioned on each identified construct according to quantitative evidence alone and qualitative and quantitative evidence combined.

	Num. studies (k)	Frequentist meta-analysis results			Likelihood		Posterior: quantitative evidence only		Posterior: quantitative evidence and qualitative evidence	
		Estimate (SMD or r-z)		*95%CI*	*Log OR*	*95%CI*	*MAP*	*95%CrI*	*MAP**	*95%CrI*
Age, years	*3*	**SMD**	0.49	[-1.01; 1.99]	-0.41	[-1.44; 0.62]	0.221	[0.217; 0.225]	0.243	[0.239; 0.247]
	12	**r-z**	-0.28*	[-0.38; -0.18]						
Comorbidity	*1*	**SMD**	-0.76*	[-1.22; -0.30]	-0.94	[-1.65 ; -0.24]	0.291	[0.245 ; 0.339]	0.232	[0.194 ; 0.273]
	1	**r-z**	-0.18*	[-0.31; -0.04]						
Social Support	*1*	**SMD**	-0.42*	[-0.15; -0.68]	0.76	[0.26 ; 1.26]	0.105	[0.080 ; 0.134	0.366	[0.327 ; 0.406]
	--	**r-z**	--	--						
Negative Attitude		**SMD**			-0.51	[-1.01 ; -0.01]	0.219	[0.174 ; 0.266]	0.222	[0.178 ; 0.268]
	1	**r-z**	-0.14	[-0.27; 0.00]						
Positive Attitude	--	**SMD**	--	--	1.02	[0.06 ; 1.98]	0.266	[0.225; 0.309]	0.330	[0.287; 0.374]
	1	**r-z**	0.27*	[0.02; 0.49]						
6MWT	*1*	**SMD**	1.00*	[0.49; 1.50]	1.77	[1.33 ; 2.21]	0.347	[0.321 ; 0.374]	0.352	[0.326 ; 0.378]
	6	**r-z**	0.42*	[0.35; 0.49]						
Functioning (self-report)	*3*	**SMD**	0.67*	[0.40; 0.94]	0.90	[0.54 ; 1.26]	0.340	[0.303 ; 0.379]	0.322	[0.287 ; 0.359]

	2	r-z	0.25*	[0.03; 0.45]						
Symptoms	--	**SMD**	--	--	0.48	[0.11 ; 0.84]	0.260	[0.236 ; 0.284]	0.316	[0.292 ; 0.341]
	1	r-z	0.13*	[0.03; 0.23]						
LVEF, %	*1*	**SMD**	-0.08	[-0.17; 0.02]	0.16	[-0.48 ; 0.80]	0.202	[0.185 ; 0.220]	0.273	[0.254 ; 0.292]
	5	r-z	0.12	[-0.15; 0.38]						
Self-Efficacy	--	**SMD**	--	--	0.84	[0.26 ; 1.41]	0.313	[0.294 ; 0.332]	0.317	[0.299 ; 0.336]
	5	r-z	0.22*	[0.07; 0.36]						
Depression	*3*	**SMD**	0.00	[-0.44 ; 0.44]	-0.54	[-1.13 ; 0.05]	0.140	[0.121 ; 0.159]	--	--
	3	r-z	-0.20*	[-0.37 ; -0.02]						
Digoxin prescription	--	**SMD**	--	--	-1.06	[-1.85 ; -0.27]	0.216	[0.150 ; 0.288]	--	--
	1	r-z	-0.28*	[-0.47 ; -0.07]						
Doppler estimated filling pressure	*1*	**SMD**	-0.39*	[-0.66 ; -0.12]	-0.71	[-1.21 ; -0.21]	0.403	[0.331 ; 0.477]	--	--
	--	r-z	--	--						
Dysphoria	*1*	**SMD**	0.21	[-0.24 ; 0.65]	0.38	[-0.41 ; 1.17]	0.241	[0.150 ; 0.343]	--	--
		r-z	--	--						
Education	*4*	**SMD**	0.06	[-0.15 ; 0.27]	0.17	[-0.15 ; 0.49]	0.288	[0.266 ; 0.310]	--	--
	1	r-z	-0.06	[-0.24 ; 0.12]						
Employment	*2*	**SMD**	-0.43*	[-0.82 ; -0.05]	-0.21	[-1.33 ; 0.91]	0.215	[0.179 ; 0.253]	--	--
	--	r-z	--	--						

Ethnicity	*2*	**SMD**	0.22	[-0.10 ; 0.54]	0.34	[-0.07 ; 0.75]	0.280	[0.248 ; 0.312]	--	--
	--	**r-z**	--	--						
HF Duration	*1*	**SMD**	-0.66*	[-1.11 ; -0.20]	-0.95	[-1.48 ; -0.42]	0.283	[0.227 ; 0.341]	--	--
	1	**r-z**	-0.20*	[-0.37 ; -0.02]						
HFrEF (Yes)	*1*	**SMD**	0.00	[-0.19 ; 0.19]	-0.22	[-1.01 ; 0.57]	0.399	[0.345 ; 0.454]	--	
	--	**r-z**	--	--						--
Pro-BNP	-	**SMD**			-1.16	[-1.52 ; -0.80]	0.142	[0.094 ; 0.197]		
	2	**r-z**	0.37	[-0.34 ; 0.81]					--	--
Hostility	*1*	**SMD**	0.43	[-0.02 ; 0.88]	0.79	[0.00 ; 1.58]	0.241	[0.150 ; 0.343]		
	--	**r-z**	--	--					--	--
Income	--	**SMD**	--	--	0.18	[-0.44 ; 0.80]	0.252	[0.192 ; 0.317]		
	1	**r-z**	0.05	[-0.13 ; 0.23]					--	--
LAV	*1*	**SMD**	-0.61*	[-0.88 ; -0.34]	-1.12	[-1.62 ; -0.62]	0.150	[0.101 ; 0.206]		
	--	**r-z**	--	--					--	--
LVAD	*1*	**SMD**	1.08*	[0.55 ; 1.60]	1.98	[1.04 ; 2.92]	0.385	[0.325 ; 0.446]		
	--	**r-z**	--	--					--	--
LVR	*1*	**SMD**	-0.11	[-0.37 ; 0.16]	-0.20	[-0.70 ; 0.30]	0.313	[0.246 ; 0.384]		
	--	**r-z**	--	--					--	--
Partner	*3*	**SMD**	-0.50*	[-0.92 ; -0.08]	-0.46	[-1.36 ; 0.44]	0.297	[0.273 ; 0.322]		--
	--	**r-z**	--	--					--	
PeakVO2	*2*	**SMD**	0.79*	[0.33 ; 1.25]	1.54	[0.71 ; 2.37]	0.283	[0.193 ; 0.380]		--
	1	**r-z**	0.57	[-0.09 ; 0.88]					--	

Perceived Exertion	--	**SMD**	--	--	-0.98	[-2.10 ; 0.14]	0.313	[0.216 ; 0.419]	--	--
	1	**r-z**	-0.26	[-0.52 ; 0.04]						
QoL	*1*	**SMD**	0.47*	[0.33 ; 0.60]	0.51	[0.11 ; 0.92]	0.243	[0.221 ; 0.266]	--	--
	1	**r-z**	0.01	[-0.17 ; 0.18]						
Renal Function	*1*	**SMD**	0.59*	[0.32 ; 0.86]	1.07	[0.57 ; 1.57]	0.216	[0.157 ; 0.279]	--	--
	--	**r-z**	--	--						
Smoking	--	**SMD**	--	--	0.66	[-0.05 ; 1.37]	0.307	[0.242 ; 0.375]	--	--
	1	**r-z**	0.18	[-0.01 ; 0.35]						
Symptoms distress	--	**SMD**	--	--	-0.46	[-0.82 ; -0.10]	0.211	[0.181 ; 0.243]	--	--
	1	**r-z**	-0.13*	[-0.22 ; -0.03]						

Note 1. Construct definitions are from the om APA dictionary, NICE (HF), TDF. 2. *MAP* –Maximum a posteriori probability estimate. 3. The expert-elicited prior distribution is summarised as *MAP* (Credible Interval), the *Beta* distribution's shape parameters (ß, œ). 4. The difference in *MAP* between physical activity in HF (general) and when it is updated with the probability of physical activity conditioned on each construct as informed by the prior elicitation task. Probability of physical activity in HF in general: *Pr*(PA|HF) = 0.32. 5. The likelihood summarises quantitative evidence as *SMD* in physical activity (95 % CI) between the exposure and control groups; or *SMD* (95 % CI) in physical activity for two categories (e.g. Age>70 vs Age<70), or *SMD* (95 % CI) in the construct between those meeting the exercise recommendation (compliant) and those not (non-compliant); or/and *r-z coefficient* (95 % CI) for the association between PA and the construct. 6. *MAP* summarising the posterior distribution elicited by updating the probability of physical activity in the general HF population (*Pr*(PA|HF) = 0.32) with quantitative evidence only. 7. *MAP** summarising the posterior distribution elicited by updating the probability of physical activity in general HF population (*Pr*(PA|HF) = 0.32) with quantitative and qualitative evidence.

5.7.8 Bayesian meta-analysis results

According to the Bayesian meta-analysis, age (*Beliefs about Capability, Capability*) is identified as a negative barrier with a relatively low uncertainty reflected in concentrated probability distribution for physical activity, Figure 5.4. Older age (>70) reduced the probability for physical activity in HF (*MAP* = 0.221). The probability distribution for physical activity conditioned on other barriers and enablers identified in quantitative evidence is highly uncertain as reflected in the dispersed distribution (Figure 5.4). Depression (*Emotion*, measured using HADS-D; CES-D; PROMIS-29) reduced the probability for physical activity in HF by twofold (*MAP* = 0.140) and instrumental social support in performing daily activities (*Social influences*) by threefold (MAP = 0.105). High pro-BNP (*Beliefs about Capability, Capability*) and LAV (*Beliefs about Capability, Capability*) reduced the probability for physical activity by twofold, *MAP* = 0.142 and *MAP* = 0.150, respectively.

Having an implantable device (LVAD, *Environmental context and resources, MAP = 0.395*), high doppler estimated filling pressure (MAP=0.403), and high 6-minute walking test result (meters, MAP = 0.347), as well as a diagnosis of HFrEF (vs HFpEF, MAP = 0.399) are identified as enablers (*Beliefs about Capability, Capability*) of physical activity in HF. However, evidence is highly uncertain, Figure 5.4.

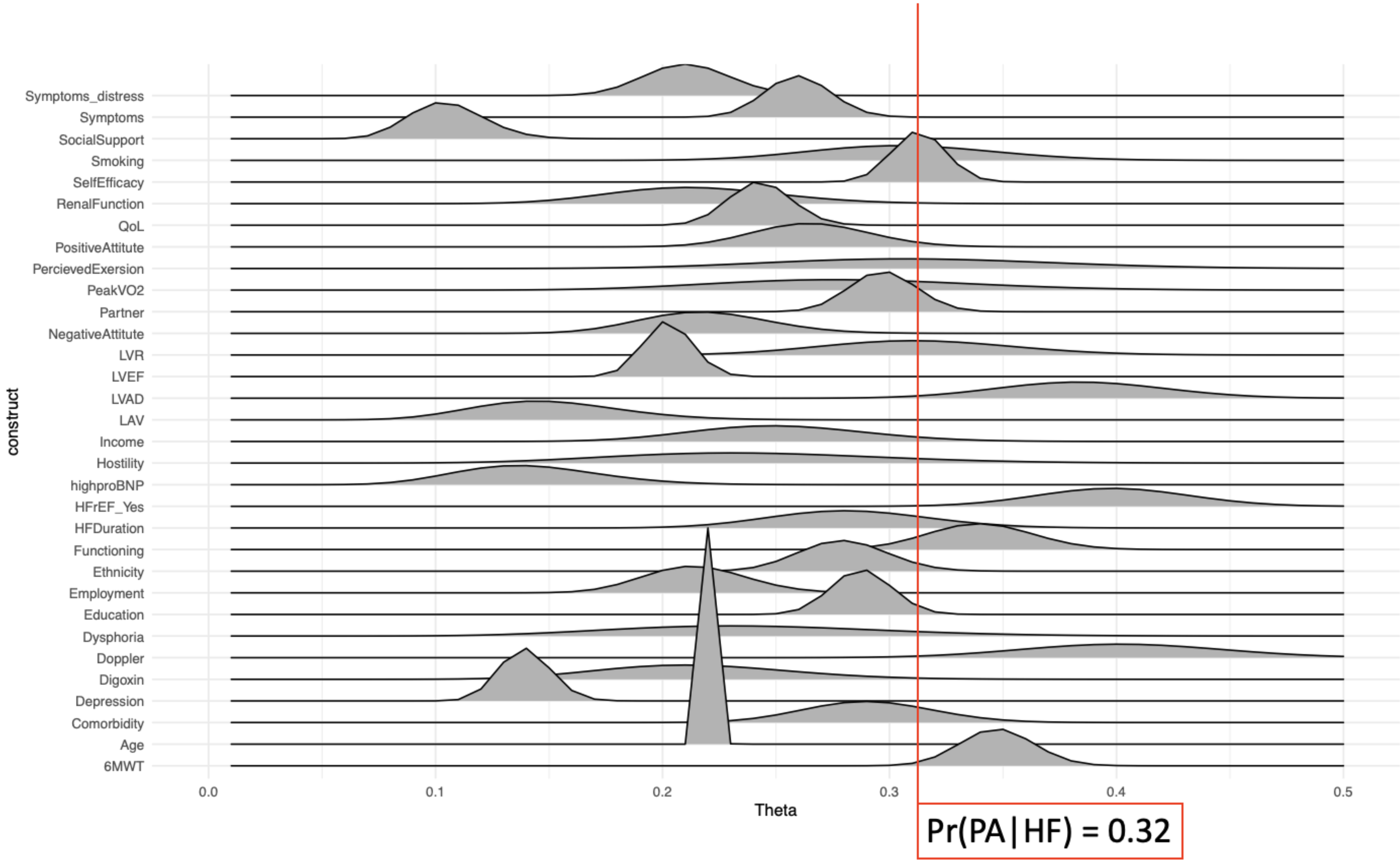

Figure 5.4. The posterior probability distribution for physical activity conditioned on identified factors as suggested by the quantitative studies.

5.7.9 An informative prior elicited from experts

The findings of the identified qualitative studies (Tierney et al., 2011a, 2011b, Pihl et al. 2011) were appraised by six experts as described in Methods. A prior elicitation task was developed to capture experts' beliefs about the probability distribution for the constructs that are present in both qualitative and quantitative evidence, after they have appraised this evidence. These included: Age, Functioning, and Comorbidity, which, in qualitative studies, were described as '*Changing Soma'*. Other constructs included: Perceived Symptoms of HF ('*Fluctuating health'*), Positive Attitude *('Mental Outlook'*), Negative Attitude ('*Negative emotional responses'*), Social Support (enabler only, described as *'Interpersonal Influences'*); and Self-efficacy ('*Not believing in one's ability'*).

The prior probability distributions for these constructs elicited from expert (N=6) are described in Figure 5.5. The summary statistics (*MAP* and *Credible Interval*) are reported Table 5.5. The general physical activity in HF summarised in empirical prior, $Pr(PA|HF) = 0.32$ (Jaarsma et al., 2013) was updated with the elicited from experts conditional probabilities. The differences in probability for physical activity (*MAP*) for physical activity in the general HF population (Jaarsma et al., 2013) and conditional on each construct probabilities are summarised in Table 5.5.

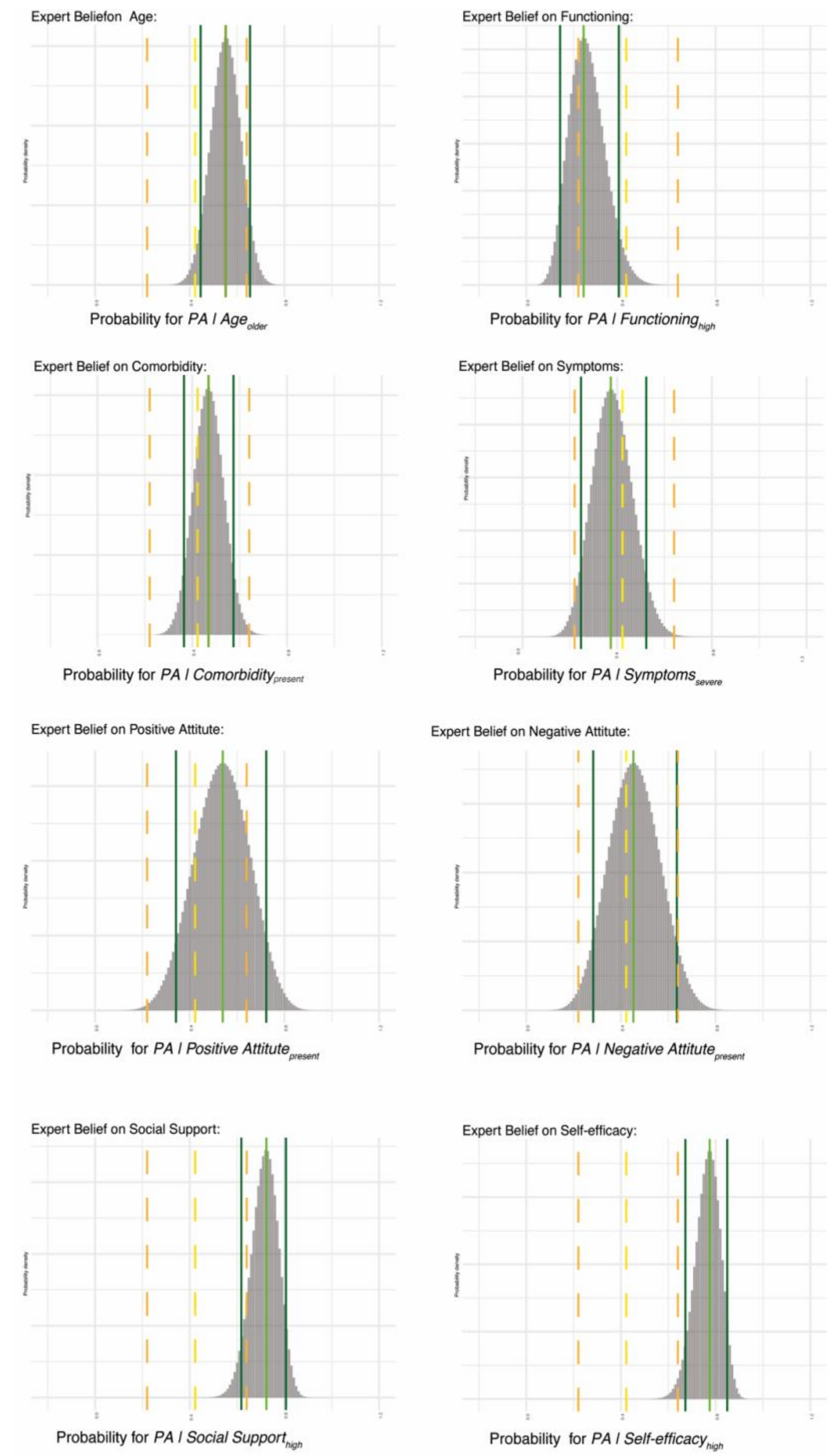

Figure 5.5. The posterior probability distribution for physical activity conditioned on identified factors as suggested by the qualitative studies (i.e., expert elicitation task results). Note: dashed lines in yellow define the Credible Interval for the MAP for the probability of physical activity in general HF population (Jaarsma et al., 2013). The probability of physical activity conditioned on each construct is in grey).

The posterior probability distributions for physical activity conditioned on each construct as suggested by either qualitative evidence alone or by quantitative and qualitative evidence combined are presented in (Figure 5.6). No important deviations are observed between two types of evidence for age, comorbidity, functioning (*Beliefs about Capability/Capability*), negative attitude and positive attitude toward physical activity (*Emotion, Optimism*), and self-efficacy (*Beliefs about Capability*) (Figure 5.6).

Qualitative and quantitative evidence concerning the probability of physical activity conditioned on social support (*Social Influences*) contradict each other (Figure 5.6). While social support (*Social Influences*) in managing HF was elicited as an enabler in qualitative evidence (i.e., expert elicitation task), it was found to reduce the probability for physical activity in a quantitative study (Gallagher et al., 2011), where it was measured using social support index (high support vs low support) developed as part of the carried out study (Gallagher et al., 2011).

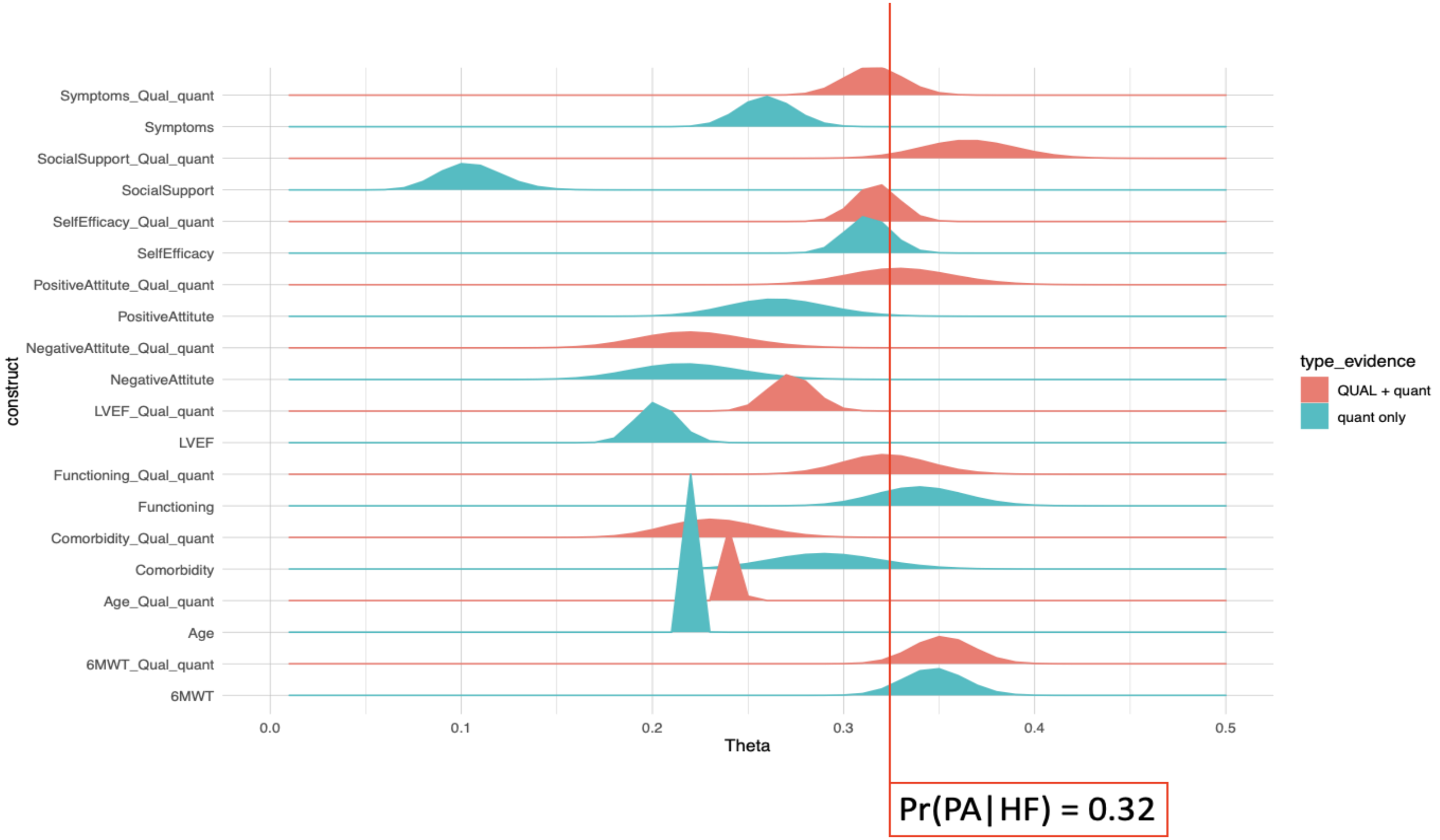

Figure 5.6. The posterior probability distribution for physical activity conditioned on identified factors according to qualitative combined with quantitative evidence (QUAL + quant) and according to quantitative evidence alone (quant).

Table 5.6. A summary of evidence across qualitative and quantitative findings

	Qualitative evidence	Quantitative evidence	Degree of uncertainty in the evidence[10]
CONTEXTUAL DETERMINANTS			
Age	Older age shaped *Beliefs about capabilities* that can be described as “changing soma”. An acceptance of the decline in physical capacity attributed to ageing process.	Older age (>65) reduced the probability for physical activity in HF by twofold. Older adults with HF is a target group for physical activity interventions. Older age may have a confounding effect in trials evaluating physical activity interventions for general HF population.	low
Depression	-	Depression reduced the probability for physical activity in HF by a factor of four. Depression may have confounding effects on physical activity and need to be considered separately by interventions designed for individuals living with HF.	moderate
Comorbidity	Perceived limitations in daily life activities attributed to comorbid conditions.	*Charlson Comorbidity Index* higher than 5 was associated with reduced probability for physical activity in HF (twofold).	high

[10] Judged from the credible interval.

Functioning	Perceived limited capacity and functioning.	Probability of physical activity conditioned on functioning was equivalent to physical activity in general HF population.	high
Income (high)	-	Probability of physical activity conditioned on income (high) was equivalent to physical activity in general HF population.	high
Education	-	High level of education (University degree) marginally decreased the probability of physical activity in HF	high
The Doppler test	-	Conditioning on the doppler test result did not change probability estimate (i.e., MAP).	high
High levels of Pro BNP	-	Conditioning on the High levels of Pro BNP blood test result did not change probability estimate.	high
Body Mass Index	-	High BMI (>28) marginally decreased the probability of physical activity in HF	high
LVEF	-	Lower LVEF (<20%) marginally decreased the probability of physical activity in HF	moderate
Implantable device	-	CRT marginally decreased the probability for physical activity as measured within one months of operation (no differences when the follow-up assessments were used check number of months). The probability distribution for physical activity did	high

		not change when conditioned on other implantable devices (LVAD).	
Symptom severity	Perceived symptoms (breathlessness and fatigue).	High symptom severity decreased the probability of physical activity in HF (0.43 compared to 0.38)	high
Ethnicity (non-Caucasian)	-	Being from a minority background (non-white, USA) reduced the probability for physical activity in HF by twofold.	high
Being employed	-	The probability of physical activity among employed individuals living with HF was lower than in those unemployed.	high
Six-minute walking test (meters)	-	Probability of physical activity conditioned on 6MWT>100 meters was equivalent to physical activity in general HF population.	high
HFrEF	-	Being diagnosed with HFrEF reduced the probability of physical activity by twofold, compared to those diagnosed with HFpEF.	high
Peak VO2	-	High exercise capacity (Peak V02) increased the probability for physical activity from 0.43 to 0.57 (Maximum aposteriori probability estimate).	high
HF duration	-	The probability for physical activity conditioned on longer diagnosis duration (>10 years) is twice as lower than the marginal probability	high

Living with a partner	-	The probability for physical activity conditioned on living with a partner was marginally reduced compared to living alone	high
QoL	-	Conditioning on QoL did not change probability estimate.	high
Dysphoria		The probability of physical activity among those with symptoms of dysphoria is twice as low than those without.	high
Local environment	Weather and seasonal changes, environment (e.g. garden).	-	**-**
Pharmaceutical treatment	Unspecified medication – enabler and barrier (side effects).	-	**-**
MODIFIABLE DETERMINANTS			
Self-efficacy (***Beliefs about capabilities***)	Perceived lack of ability to engage in physical activity. Theme: *'Not believing in one's ability.'*	The probability of physical activity conditioned on self-efficacy is lower to marginal probability.	high
Emotion and Optimism: Positive attitude	Positive attitude toward physical activity and optimistic beliefs about physical activity	The probability of physical activity conditioned on positive attitude is lower compared to marginal probability.	high

Negative attitude	*'Negative emotional responses' theme included:* emotional response toward physical activity that impacted willingness to engage in physical activity optimistic beliefs ('*Not knowing when they would experience deterioration in health made certain patients feel helpless'*).	The probability of physical activity conditioned on positive attitude is lower compared to marginal probability.	high
Social Influences:			-
Social support (enabler)	Perceived peer support (exercising with others); emotional support (exercising with a friend).	The probability of physical activity conditioned on social support is equivalent to marginal probability.	high
Social influence (barrier)	Perceived interpersonal influences of family and others (barrier). Receiving help in activities (loss of independence).	-	-
Social pressure	Others' expectations about physical activity levels performed by someone with HF.	-	-
Credible source	Perceived reassurance from a health professional about safety physical activity (type such as resistance training, amount, intensity).	-	-
Outcome expectancies (positive, ***Beliefs about consequences***)	Beliefs about cardiac health, quality of life improvements contingent on physical activity		-

Behavioural regulation:			
Problem solving	Troubleshooting to overcome unpredictability of fluctuating symptoms and plan physical activity in the face of this barrier.	-	-
Action planning	“Need of finding practical solutions in daily life”	-	-
Self-identity/social role (***Social professional role and identity***)	Perceived change in self-concept (following HF diagnosis) and perceptions about oneself attributed to ageing and lack of physical capacity. Theme: ‘Losing one’s social role in daily life’	-	-

Table 5.7. A summary of evidence across qualitative and quantitative findings.

TDF domain suggested by the findings of the systematic review	Type of evidence	Degree of uncertainty (based on the credible interval)	Proposed behaviour change techniques (Michie et al., 2013, BCT v1.)	COM-B
Environmental Context and Resources	**QUAL and quant**	*High*	*Adding objects to the environment, Prompts/cues, Avoidance/changing exposure to cues for the behaviour*	Physical Opportunity
Social Influences	**QUAL and quant**	*High (more research is required)*	*Social support (unspecified), Social support (emotional)*	Opportunity
Beliefs about Consequences	**QUAL**	*High (more research is required)*	*Information about consequences, Salience of consequences, Feedback on behaviour, Feedback on the outcome of behaviour, Pros and cons, Emotional consequences, Covert sensitisation, Anticipated regret, Comparative imagining of future outcomes, Vicarious reinforcement*	Reflective Motivation
Beliefs about Capabilities	**QUAL and quant**	*Low for older age* *High for other constructs (more research is required)*	*Behavioural practice and Rehearsal, Graded tasks, Social comparison, Focus on past success, Verbal persuasion about Capability*	Psychological Capability
Behavioural Regulation	**QUAL**	*High (more research is required)*	*Action planning, Self-monitoring behaviour, Problem-solving, Goal setting outcome, Self-monitoring, Feedback on behaviour, Habit formation*	Psychological Capability
Emotion/optimism	**QUAL**	*High (more research is required)*	*Reduce negative emotions, Information about health consequences, Information about emotional consequences*	Automatic Motivation

5.8 Discussion

The aim of this systematic review was to identify, describe and compare clinical, demographic, and psychosocial barriers/enablers to physical activity in HF. Both, qualitative and quantitative studies were included in the review. A total of 28 peer-reviewed studies were included in the review. A total of 27 of which were included in the Bayesian meta-analysis. The evidence was drawn from cross-section studies (57%), case-controlled studies (7.1%), and cohort studies (21.4%). 10.71% of the identified studies were qualitative and were, therefore, described in an informative prior using established methods of prior elicitation, namely an expert elicitation task. The evidence in support of each of the identified determinants, either increasing the probability of physical activity (enabler) or decreasing (barrier) was summarised for each univariate relationship with physical activity.

The following constructs were assessed quantitatively and identified in qualitative evidence. Age and the beliefs surrounding the process of ageing. Self-reported levels of functioning and beliefs about functioning limitations. Self-reported extent of comorbidity (described below) and personal accounts of how comorbidity limits physical activity. Levels of perceived symptom severity and reports about symptom experience and its impact on physical activity. Social support, self-efficacy, positive and negative attitudes were described in both qualitative and quantitative studies.

The following domains were identified as relevant in qualitative evidence *Behavioural Regulation*, *Environmental Context and Resources*, *Beliefs about Capabilities*, *Beliefs about Consequences*, *Social Influences*, *Social Professional Role and Identity* (change in self-concept and perceptions about oneself attributed to ageing), and *Emotion*.

Quantitative evidence assessed domains such as *Beliefs about Capabilities* (self-efficacy, comorbidity, functioning), *Beliefs about Consequences* (perceived symptoms and symptoms distress), *Social Influences* (partner and social support), *Social, Professional Role and Identity* (employed vs unemployed), *Emotion* (positive attitude, negative attitude, depression, dysphoria). The factors that were assessed quantitatively were described in terms of the precise definitions provided by the authors. Therefore, to preserve the specificity of constructs in the meta-analysis they were not aggregated into domains.

5.8.1 Contextual barriers

Clinical and demographic factors provide a contextualised understanding of how best to improve physical activity in HF population subgroups. This review identified the following contextual barriers: age, employment, living with a partner, depression, recent surgery, comorbidity, HF diagnosis duration.

This meta-analysis suggests with high certainty that older age is a significant barrier to physical activity in HF. This result further reiterated the finding of a meta-analysis of RCTs evaluating physical activity interventions (Amirova, Fteropoulli, Williams, & Haddad, 2021) that older adults living with HF need more support in attaining higher levels of physical activity. It is important to explore beliefs about physical activity that are associated with older age.

The findings of the review concerning employment are in accord with the findings of a qualitative semi-structured interview study with a non-clinical sample of adults transitioning to retirement (McDonald, O'Brien, White, & Sniehotta, 2015), which found that retirement is perceived as providing opportunities to become physically active. On the other hand, authors also reported that this was not always the case, and an individualised approach may be required (McDonald et al., 2015). Context, social norms surrounding physical activity in older age may impact how physical activity is enacted in older adults who transitioned to retirement (Koeneman, Chorus, Hopman-Rock, & Chinapaw, 2017; McPhee et al., 2016). Country-hosts for the included studies may vary in terms of cultural contexts or other higher organisational and contextual characteristics, which are not within the scope of this review.

Depression lowered the probability of physical activity as identified by the quantitative evidence. Depression is a considerable burden in HF. It is associated with poor adherence to pharmaceutical treatment (Goldstein, Gathright, & Garcia, 2017). Depression is an independent predictor of morbidity (Moudgil & Haddad, 2013). The physiological factors perpetuating depression in HF include inflammation, blood cell abnormalities, CNS changes and changes in health-protective behaviours (Huffman, Celano, Beach, Motiwala, & Januzzi, 2013). The association between depression, HF, and lack of physical activity is complex. HF, like any cardiovascular disease, is a consequence of low physical activity in clinically depressed individuals (Gold et al., 2020). More research investigating the mechanism via which depression impacts physical activity in HF, as well and how to mitigate it, is needed.

Non-cardiovascular comorbidities in HF include Diabetes Meletus (type 2), chronic obstructive pulmonary disease (COPD), and renal dysfunction (Rushton, Satchithananda, Jones, & Kadam, 2015). These comorbidities increase both morbidity and mortality in HF (Rushton et al., 2015). A frequent cardiovascular condition that accompanies HF is atrial fibrillation (AF) (Ling, Kistler, Kalman, Schilling, & Hunter, 2016). Another clinical barrier identified by the present review is longer HF duration which is likely to result in deterioration of functionating. The diagnosis of HFrEF, as well as its duration, may engender a higher risk of physical *in*activity than the diagnosis of HFpEF. However, the available evidence is uncertain, and more evidence is needed before drawing any definitive conclusions.

5.8.2 Contextual enablers

Clinical enablers include HFrEF (vs HFpEF), exercise capacity, functioning, 6-minute walking test, doppler estimated pressure, Peak V02, and LVAD implant.

These contextual barriers and enablers need to be carefully considered in both future cross-sectional studies and in randomised-controlled trials evaluating the mechanism of change. Understanding the contextual factors influencing behaviour is useful in informing the design of a quantitative research study investigating modifiable factors influencing physical activity (Rothman, Lash, & Greenland, 2008). However, contextual understanding does not provide insights into what can and needs to be changed in order for these demographic and clinical subgroups of HF population to engage in physical activity. This provides a strong rationale for_research on psychosocial (i.e., modifiable) correlates of physical activity in HF.

5.8.3 Modifiable barriers

The review informs the intervention development by identifying relevant barriers and enablers, the level of uncertainty in the evidence and proposed strategies that target the relevant modifiable barriers and enablers (Table 5.8).

A quantitative study assessed differences in physical activity in people with high vs low perceived social support and identified social support as a barrier (Ghalagher et al., 2011). On the other hand, qualitative evidence uncovered both positive and negative influences of social support on levels of physical activity (Pihl et al., 2011). This included caregivers shielding individuals with HF from any physical activity by overtaking their daily responsibilities. Activities of daily living, including stairs, climbing, walking, and housekeeping, degrade with loss of function and independence (Norberg et al. 2008). The qualitative studies identified by this review suggest that these activities are vital to people living with HF in preserving their independent functioning. Albeit, their social support system (e.g. family and friends) may limit their independence in carrying out these activities (Pihl et al., 2011). There are two likely explanations for this divergence. Either quantitative studies are subject to a measurement error and require a finer and more nuanced understanding of social influences on physical activity in HF. Alternatively, qualitative research overestimates the impact of social influences. Both possibilities should be explored in future research. If two qualitatively different aspects of social influence are aggregated in quantitative assessment, it might reduce the accuracy of the quantitative prediction.

5.8.4 Modifiable enablers

The qualitative studies provided the perspective and views on physical activity shared by individuals with HF. An identified overarching theme in one of the qualitative studies was 'Having realistic expectations about the future', which was annotated as outcome expectancies, Beliefs about Consequences. Environmental Context and Resources domain summarised all external to the individual factors that may impact physical activity levels. This included weather, pollution and transport, and pharmaceutical treatment; and was summarised as a broad theme of 'General social and environmental factors'. Social influences were collectively described within that theme. Behavioural Regulation included a theme such as the 'need of finding practical solutions in daily life, which in this review is described as problem solving. Overall, three domains were identified uniquely in qualitative research. However, these were not followed up with a quantitative study to confirm their relevance in a larger sample. These insights from qualitative studies should be further confirmed in future quantitative research. After observing the qualitative evidence, this review suggests exploring and confirming the role of social support (barrier and enabler) and self-efficacy in a quantitative study.

Overall, while there is substantial evidence for the contextual barriers and enablers, less is known about modifiable barriers and enablers. The latter needs further research as this will improve the understanding of how best to improve physical activity in behaviour change interventions.

5.8.5 A discrepancy between qualitative and quantitative evidence

A discrepancy was identified between the evidence on social support provided only from quantitative studies, and the evidence from qualitative and quantitative studies combined, as indicated by Bayesian updating. The discrepancy and its implications are described below.

While quantitative studies assessed social support as the potential covariate of physical activity and found no association, qualitative evidence uncovered both positive and negative influences of social support on levels of physical activity (Pihl et al., 2011). This included caregivers shielding individuals with HF from any physical activity by overtaking their daily responsibilities. Activities of daily living including stairs, climbing, walking, and housekeeping degrade with loss of function and independence (Norberg et al. 2008). The qualitative studies identified by this review suggest that these activities are vital to people living with HF in preserving their independent functioning. Albeit, their social support system (e.g. family and friends) may limit their independence in carrying out these activities (Pihl et al., 2011).

Thus, it is likely that there are two explanations for this divergence. Either quantitative studies are subject to a measurement error and require finer and more nuanced understanding of social influences on physical activity in HF. Or alternatively, qualitative research overestimates the impact of social influences. Both possibilities should be explored in future research. If two qualitatively different aspects of social influence are aggregated in quantitative assessment, it might reduce the accuracy of the quantitative prediction. After observing the qualitative evidence this review suggests exploring and confirming the role of social support (barrier and enabler) and self-efficacy in a quantitative study.

5.8.6 Limitations of the review

The AMSTAR 2 (Shea et al., 2017) is attached in Appendix M. Currently, there is no standardised risk of bias assessment for observational studies (Page et al., 2018). Therefore, this review included the evolution of the categories of bias sources that are traditionally proposed for the assessment of study-level biases. These include confounding bias, selection bias, measurement bias, missing data bias, and reporting bias. The Working group for the Bank of Items for Risk of Bias (Viswanathan et al. 2013) proposed biases introduced by inappropriate statistical analysis. These collectively formed the criteria for evaluating the risk of bias across the included studies. Overall the study level bias was low for the majority of the included studies (69.23%) and moderate for 19.23% of the included studies.

The choice of hyperprior may impose some limitations on the review. All Bayesian priors are assumptions. The choice of a prior is defined by the objectives and research questions of a study (Lemoine, 2019; Lewis & Nair, 2015; Newman, Jacobs, & Bartram, 2007). In this review, the objective was to compare barriers and enablers in the context of low physical activity in HF. A non-informative prior is much too conservative to be useful for this (Chen, Ibrahim, & Kim, 2008). A non-informative prior would assume that people with HF engage in physical activity as much as any population group, which is known to not be a valid assumption (O'Donnell et al., 2020). There should be lower prior probability for events like "100% of HF patients engage in physical activity" than for events like "10% of HF patients engage in physical activity". Thus, an empirical hyperprior was elicited from a large study on the engagement of physical activity in HF (Jaarsma et al., 2013). The use of this informative hyperprior should be seen as an attempt to improve upon what would otherwise be an even less valid assumption, generating an even greater bias. However, large-scale evidence on the general levels of physical activity in HF exists in a binary form only (Jaarsma et al., 2013). The choice of this hyperprior while being well-fitted for the objective resulted in the dichotomisation of physical activity outcome. Dichotomisation of a continuous variable generates a high risk of bias. To overcome this bias, it is advised to obtain a distribution of physical activity in a large representative sample. For example, Biobank studies investigating physical activity may provide large data sets on detailed physical activity behaviour. If possible, physical activity in HF should be assessed as a continuous variable measured using an accelerometer. As always, changes in the findings resulting from using a different informative prior may be assessed in a sensitivity analysis.

It is likely that the relationship between physical activity and the identified barriers and enablers are bidirectional. On the other hand, the attribution of causes of physical activity in qualitative studies (Tierney et al., 2011) indicates that people with HF list social support and self-efficacy as causes of physical activity and not vice versa. However, this meta-analysis offers claims about association not causality. Therefore, it is still not known why and how exactly the identified determinants cause or prevent physical activity enactment. Currently, an ontology is being developed to help in formulating causal claims and seek evidence supporting them (Michie & Johnston, 2017; West et al., 2019). In helping to inform physical activity interventions, this framework can be potentially applied to assess relevant causal assumptions against evidence present in this chapter in combination with other evidence on physical activity (Michie & Johnston, 2017; West et al., 2019) . Likewise, but on a much smaller scale, the evidence provided in this chapter will inform computational modelling reported in Chapter 7.

A challenge faced by the experts who appraised qualitative evidence was as follows. When responding to the elicitation task it was challenging to describe functioning and comorbidity in HF in terms of TDF domains. This often resulted in aggregation of these factors with a perceived ability (i.e. self-efficacy). Functioning and comorbidity otherwise could have been defined in terms physical functioning and comorbid illnesses in HF (as measured with precision in quantitative research), Capability within the COM-B model (Susan Michie, van Stralen, & West, 2011) or Common Sense Model, CSM (Leventhal, Meyer, & Nerenz, 1980; Leventhal, Phillips, & Burns, 2016). A more structured description of both comorbidity-related Beliefs about Capabilities and self-efficacy-related beliefs about capability are of interest to future research.

The probability of physical activity conditioned on self-efficacy as supported by qualitative evidence was larger than its probability when both quantitative and qualitative evidence were considered. On the other hand, functioning and comorbidity are supported as relevant barriers by quantitative research to a greater extent than qualitative research. One theme identified by Tierney et al. (2011) was "not believing in one's own ability" and it included descriptions of comorbidity and other beliefs collectively. This suggests the potential relevance of the comorbidity-related beliefs to the perceived ability to engage in physical activity. This is a valuable insight. However, comorbidity, self-efficacy and functioning should be explored further to seek detailed understanding of beliefs about self-efficacy, functioning, and comorbidity as separate influences on physical activity, as well as influences that jointly result in the lack of physical activity.

A prior summarising qualitative evidence was elicited using a prior elicitation task administered to a panel of experts. It may have elicited cognitive biases. It is important to note that the experts were health psychology researchers and therefore the implications of psychosocial determinants (e.g. self-efficacy) were more salient to them than clinical determinants (e.g. functioning, symptom severity). One of the researchers had expertise in cardiovascular conditions research. Another member of the panel – the author of the thesis – is also aware of the extent to which symptoms and functioning limit physical activity HF. These two coders appraised the clinical factors to be more salient than the psychologists specialising in other conditions and physical activity. However, they too appraised social support and self-efficacy as more influential on physical activity than comorbidity, but not symptom distress. Therefore, it is recommended to seek appraisal of the qualitative evidence by a multidisciplinary team including cardiologists and HF nurses. This might shed light on whether the probabilities conditioned on social support and self-efficacy are relevant reflections of the qualitative findings or more due to cognitive biases caused by the speciality of the experts.

5.8.7 Strengths of the review

Reasoning about the determinants of complex behaviour is highly uncertain due to the complexity of the underlying processes (Craig et al., 2008). On the other hand, the choice of intervention is guided by the trade-off between the costs and benefits to be obtained. Reasoning about evidence on behaviour change can be informed by answering the following three questions: a) ‘How likely is the behaviour in the general population conditioned on a behavioural determinant?’ b) ‘Are there differences between qualitative and quantitative evidence?' c) 'How much does one determinant increase or decrease the probability of physical enactment?' and 'How certain is this evidence'? A Bayesian approach (Spiegelhalter 2004) is equipped for considering these questions. This will be outlined below.

5.8.7.1 How likely is the behaviour in the general population conditioned on a behavioural determinant?

The Bayesian framework enabled the researcher to integrate contextual evidence. In this study general physical activity levels in HF were used to provide this context. Probability of mild-moderate-vigorous physical activity in HF is only 43% based on the evidence drawn from individual data meta-analysis (Jaarsma et al., 2013). This method also facilitates situating the evidence regarding barriers or enablers to behaviour in the context of prior evidence. In this study, the predictive distributions for physical activity given each barrier or enabler are situated in the context of low levels of physical activity in HF.

5.8.7.2 Are there differences between qualitative and quantitative evidence?

This review was able to integrate relevant evidence despite inconsistencies in epistemological stance and research design adopted by the evidence-generating process. This was facilitated using the prior elicitation task, which then could be combined with the quantitative evidence. Such Bayesian updating of the probability of physical activity in HF conditioned on each construct reflects both qualitative and quantitative evidence. This approach was first implemented by Dixon-Woods et al. (2003) and their methods were closely followed for the analysis of this review. Dixon-Woods et al. (2003) advocate for integration of qualitative research in healthcare decision making because it provides valuable insights and places the patient in the heart of care by bringing their perspective into account. An interesting result along these lines of the present review is the importance of investigating what makes social support a barrier and what makes it an enabler of physical activity in HF. The method also highlighted inconsistent conclusions concerning self-efficacy and social support between qualitative and quantitative evidence.

5.8.7.3 How much does the probability of physical activity enactment increase or decrease when conditioned on a determinant? How certain is this evidence?

The present review draws comparative predictions about physical activity conditioned on a barrier or an enabler. This was done by comparing marginal probabilities to probabilities conditioned on a barrier or an enabler (Spiegelhalter et al., 2003). The extent of certainty in the evidence and the associated likelihood of physical activity provide the measure of the strength of relevance of each barrier or an enabler. This helped to conclude that age, comorbidity, negative attitude and depression are considerable barriers. The influences of other identified factors, for which the evidence is uncertain (i.e. wide credible intervals), are left as tentative hypotheses to be further tested. Such a procedure helps researchers make conclusions based on the relevant importance of one barrier or enabler to physical activity in comparison to other barriers and enablers.

5.9 Conclusion

To summarise, the evidence drawn from both qualitative and quantitative studies identifies the following barriers to physical activity: age, comorbidity (*Beliefs about Capabilities*), and negative attitude (*Emotion*). While there is a low degree of uncertainty in evidence on the influence of older age on physical activity, more research into the impact of comorbidity and negative attitude is required.

The quantitative evidence alone suggests that the physical activity probability is reduced in the presence of depression (*Emotion*). The quantitative evidence on physical activity probability conditioned on other clinical, demographic, and psychosocial barriers and enablers is uncertain. Research is required to understand the mechanism via which depression impacts physical activity in HF as well as study a broad range of clinical, demographic, and psychosocial barriers and enablers.

Social support and self-efficacy were identified as enablers in qualitative studies. However, this was not supported by quantitative studies. Thus, it is necessary to further investigate under what conditions social support and self-efficacy influence physical activity in HF. Qualitative evidence suggests that social influences (e.g. family and friends) may limit people living with HF in performing physical activity. This suggests that the attributes that define how social support affect physical activity should be further studied.

Finally, less is known about other psychosocial (i.e., modifiable) determinants of physical activity in HF. Physical activity is a complex behaviour and is subject to a myriad of factors, and relationships among them are complex. Therefore, a detailed understanding of modifiable factors, such as needs and beliefs, is required. The present thesis, therefore, is set out to fill the gap in knowledge by building broad and detailed understanding of modifiable factors influencing physical activity in HF in the next chapters.

6 Perceived Barriers and Enablers of Physical Activity in HF: A Qualitative Semi-Structured Interview Study

6.1 Introduction

The systematic review (Chapter 4) identified that only a small number of theories were applied in the development of existing interventions aimed at changing physical activity in HF. Social Cognitive Theory (Barnason et al., 2003; Duncan & Pozehl, 2003; Smeulders et al., 2010), Motivational Interviewing (Brodie et al., 2008) and the Transtheoretical Model of Change (O'Connor et al., 2009) were evaluated on the subject of its relevance to physical activity in HF. The systematic review and meta-analysis (Chapter 4) indicated that application of behaviour change theories is potentially promising in designing efficacious interventions, however, the use of theory across the evaluated trials was limited.

An explicit understanding of how a behaviour is enacted is recommended by the Medical Research Council Guidelines (Craig et al., 2008; O'Cathain et al., 2019) for the development of complex interventions. As reported in Chapter 3, an understanding of the potential factors and relations among them (mechanism) can guide the choice of theory, thus informing development and delivery of future interventions.

Physical activity in HF is complex and is subject to many clinical and psychosocial factors specific to this population. However, little is known about what they might be (Tierney et al., 2011). Tierney and colleagues (2011a) recommend further investigation of these factors. The systematic review of factors influencing physical activity in HF (Chapter 5) suggests that LVEF (<20%), age and depression are key barriers to physical activity in

HF. It is however unclear what are the *modifiable* factors. It is also unclear how exactly depression results in low levels of physical activity and what can be done to mitigate that. Thus, the mechanism via which these non-modifiable and difficult to change factors result in reduced physical activity is under-defined.

To further investigate these factors and the mechanism via which they influence physical activity in HF, an exploratory sequential mixed-methods study was designed to identify and describe barriers and enablers of physical activity in HF (Background to mixed-methods is reported in Appendix L).

As reported in Chapter 4 the very few (n=5) trials that evaluated the efficacy of existing interventions for a representative sample (age 70 and above) consistently found a lack of efficacy. Age is a substantial barrier to physical activity as identified by the systematic review and meta-analysis reported in Chapter 5. Therefore, this study focuses on understanding barriers and enablers in older adults in HF.

Barriers and enablers to being physically active are subjectively experienced by an individual with HF. Therefore, it is first required to explore a broad set of barriers and enablers as perceived by people with HF, before defining the variables of the quantitative study. This ensures that the perspective of people with HF is accounted for in the design of the quantitative study. The present chapter reports the first phase of this study – the qualitative study using semi-structured interviews. The first phase systematically explores perceived clinical, environmental, and psychosocial barriers and enablers using Theoretical Domains Framework (Cane et al., 2012).

6.2 Aims

- To gain an understanding of the perceived barriers to and enablers to physical activity in older adults with HF;
- To generate hypothesis that can be tested in the subsequent quantitative study.

6.3 Objectives

- To identify and describe perceived barriers to and enablers of physical activity in older adults with HF. This includes:

Identifying relevant theoretical domains;
Generating domain-specific belief statements that play an explanatory role in physical activity in HF;
Formulating these beliefs statements as corresponding theoretical constructs;
Eliciting domains that are relevant to physical activity in HF using Theoretical Domains Framework.

6.4 Research questions

- RQ1. What are the perceived barriers to and enablers of physical activity in older adults with HF?
- RQ2. How are these barriers and enablers causally related as perceived by older adults with HF?

6.5 Methods

6.5.1 Epistemological stance of the project

The main epistemological stances that have been traditionally juxtaposed in research are positivism/post-positivism and constructivism/interpretivism (Creswell & Plano Clark, 2011). The positivists suggest a singular reality that can be investigated using objective and value-free inquiry underpinning quantitative research methods. This is contrasted with the constructivists' standpoint suggesting a concept of subjective reality, which is most appropriately investigated using qualitative research methods (Creswell & Plano Clark, 2011). This study does not take either a positivist or constructivist stance and chooses pragmatism (Rossmann & Wilson, 1985) as an epistemological stance for the following reasons.

Firstly, this approach strives to employ multiple world views in order to address a research problem in a useful and comprehensive way (Rossman & Wilson, 1985) which sits well with the objective of this project (i.e., to provide a comprehensive account of factors that may influence physical activity in HF). Pragmatism enables the researcher to provide the participants' perspective using methods of investigation offered by the health psychology discipline and allows the combination of qualitative and quantitative methods effectively (Creswell & Plano Clark, 2011). This will help in producing a more comprehensive understanding of factors that may influence physical activity in HF.

Secondly, pragmatism is a problem-centred and practice-oriented approach to research (Creswell & Plano Clark, 2011), making it the most suited stance in addressing this project's pragmatic purpose, namely, to inform the development of a physical activity intervention for individuals with HF. By adopting this approach, the focus is placed on future applications of this research, namely, to inform the development of a physical activity intervention.

6.5.2 Design

Semi-structured interviews guided by a TDF-based interview schedule were carried out.

6.5.3 Inclusion criteria

Individuals diagnosed with HF according to the current diagnosis criteria outlined by the European Society of Cardiology (Ponikowski et al. 2016) were recruited to take part in this study. Only clinically stable HF patients were recruited. Clinically stable HF patient was defined as someone who has not experienced a change in their condition's severity (NYHA class) or medical regimen in the past three months. The clinical assessment of the stable condition was carried out by a health professional at the recruitment site (Royal Brompton and Harefield Hospital NHS trust). It was chosen to limit the inclusion criteria to older adults (≥70 years old). This decision was made based on the systematic review and meta-analysis reported in Chapter 4, which identified that older adults are under-represented in research studies. Meanwhile, the older population group is most at risk of a sedentary lifestyle (Evangelista et al., 2003; Gonzalez et al., 2004; Chien et al., 2014). To take part in the study participants were required to be able to provide informed consent and to converse in English. If a participant did not wish to read the information sheet, but still expressed an interest, the consent form and information sheet were read to them outload.

6.5.4 Exclusion criteria

Individuals with uncontrolled angina or severe HF (New York Heart Association class IV) were not recruited, due to their experiencing severe physical limitation in performing physical activity and safety consideration. In addition, anyone who was recommended to avoid exercise or any moderate or strenuous physical activity by a healthcare professional, was not invited to take part in the study.

6.5.5 Setting and recruitment

Participants were recruited from outpatient cardiology clinics at the Royal Brompton & Harefield NHS Foundation Trust. Individuals with HF who meet the inclusion criteria were identified by a member of the clinical team and asked if they were interested in the study. The author of the thesis attended weekly clinics and waited outside the appointment room. She was called by the clinical team member if the patient expressed an interest in taking part in the study. Those who expressed an interest were introduced to the author of the thesis. Each participant was provided with a participant information sheet (PIS) and informed consent form (ICF). The researcher described the study aims, objectives, and procedure in more detail and answered participants' questions about the study. Individuals who expressed an interest in taking part in the study, were given an option to consider their participation over 24 hours. Those who decided to take part were asked to sign the ICF.

6.5.6 Sampling strategy

Individuals aged 70 years and over were purposefully recruited. The criterion sampling strategy has been designed to reflect the diversity and breadth of this population (Ritchie & Lewis, 2003) within pragmatic limits. Given the evidence suggesting that NYHA class limits physical activity, as supported by the literature review (Chapter 5) these clinical and demographic characteristics were chosen as criteria for the sampling strategy. Individuals within different NYHA classes (I, II, III) and both genders were purposely recruited.

6.5.7 Sample size

Purposive sampling strategy, described by Sandelowski et al., (1995), was employed to calculate the minimum sample size. The sample is homogeneous in terms of age (>70 years). To have maximum demographic variation (both genders), and to have maximum phenomenal variation (severity of HF as indicated by NYHA class: I, II, III) we accounted for these criteria. It was planned to have two participants of each gender within each of the NYHA classes (2x3 NYHA classes x 2 genders). Using this purposive sampling strategy, the minimum sample size for initial analysis was 12 participants. The purposeful sample was aimed to be expanded only if the data obtained from the participants already sampled was deemed insufficient, in the case when the data saturation has not been reached. In line with the guidelines for reaching saturation we employed a method outlined by Francis et al. (2010). This included the following decision making. Initially, a total of 12 participants were recruited. Then, three consecutive interviews were conducted. If no new beliefs emerged as the result of the additional three interviews the study recruitment was stopped. Therefore, the total sample is estimated to be 15 people. If saturation was not reached by the point of having recruited 15 interviews, up to 18 interviews were recruited. The initial analysis was conducted concurrently to recruitment. At this stage only a single coder performed the analysis.

6.5.8 Data extraction

Age, sex, level of education, ethnicity, marital and occupational status were recorded using self-reports. Information on the duration of HF diagnosis, comorbidities, NYHA class, LVEF (%) at the most recent clinical assessment, medication, and the frequency of hospitalisation in the past year was extracted from clinical records immediately after or the following week. Comorbidities were additionally assessed using a standard self-report checklist (Elixhauser, Steiner, Harris, & Coffey, 1998). The medical records data extracts were matched to the participant identification number and entered into an Excel file.

6.5.9 Procedure

After providing an informed consent, participants took part in a single semi-structured interview. The researcher arranged for the interview to be conducted at a convenient time and place suited to the participant. Participants were offered an option to be interviewed at City, University of London premises, in a suitable room at the clinic (e.g. vacant consultancy room), research rooms available at the clinic, at the participants' home, or via telephone. All participants opted in for a research room, clinic consultation room or telephone. The interviews were conducted by the author of the thesis, who has been trained in conducting qualitative interviews and practiced with colleagues. The author asked participants to describe their physical activity levels and explored potential barriers and enablers to performing physical activity.

6.5.10 Interview schedule

A flexible interview schedule was developed (Appendix O). The schedule was designed to elicit the description of everyday physical activity. It then explored how physical activity has changed since HF diagnosis, to assist the participant in expressing beliefs that are relevant to HF. The schedule then followed with TDF-informed prompts. The prompts did not need to be presented in any order and could be a part of a natural conversation instead.

6.5.11 Development of the interview schedule

TDF was applied in the design of the semi-structured interview schedule. It has been suggested that TDF-based semi-structured interview helps in eliciting a greater number of relevant barriers and enablers, whereas unstructured interviews or less structured interviews result in identification of only some, usually the most salient, barriers and enablers (Francis et al., 2009). Thus, TDF-based semi-structured interviews are expected to facilitate the search for a broader range of domains that are perceived as relevant to physical activity by individuals living with HF.

The author of the thesis designed interview prompts with an aim to elicit both broad and specific responses. The interview schedule was discussed with the team of supervisors, who have expertise in implementing the TDF as a topic guide as well as expertise in behaviour change theories. Then the interview schedule was presented to another six health services researchers with expertise in TDF-informed research and/or health research management.

The feedback on the content and structure of the interview schedule was received from a cardiologist, a HF-specialist nurse, and two individuals diagnosed with HF, who are members of the Patient-Participant Committee at the ‘Public Involvement in Research Forum, Cardiovascular Biomedical Research Unit, Royal Brompton and Harefield, NHS Foundation Trust. The interview schedule was amended following this feedback. One individual with HF participated in a pilot interview and provided their feedback on the structure of the interview and length.

6.5.12 Reflection and reflexivity

The author of the thesis engaged in reflection and reflexivity throughout the study. The recommendations for conducting qualitative research outlined by Symon and Cassell (2012) was followed. A research diary was kept, where reflective notes on the data and analysis process (*reflection*) were recorded in detail. The researcher’s theoretical assumptions about physical activity in HF were acknowledged before the start of the interviews. These assumptions and how they might have shaped the research question of the project were considered throughout the study (*reflexivity*). Notes were taken on the researcher’s interaction with the participants and the effect the researcher had on the research process and the findings. These notes were discussed with one of the members of the research team (*reflexivity*).

6.5.13 Data analysis

With the participants’ consent, interviews were audio-recorded and transcribed verbatim. The audio-recordings and the transcripts were pseudonymised by assigning a participant identification number to each interview. Interviews were collected and analysed concurrently to enable an on-going check of saturation. The analysis was facilitated using NVivo 12 software.

6.5.13.1 Analysis based on the Theoretical Domains Framework (TDF)

The five steps recommended for conducting TDF-based interviews (Atkins et al., 2017); Islam et al., 2012) were followed as described below.

6.5.13.1.1.1 Coding the interview transcripts

A line-by-line analysis of each transcript involved categorising monothematic parses of text referred to as ‘quotes’ (e.g. phrase, sentence, a collection of sentences conveying a single meaning) into TDF domains. For each domain, the quotes with a shared underlying meaning were then summarised into belief statements.

6.5.13.1.1.2 Inter-rater reliability of coding and coding scheme

Some argue that inter-coder agreement does not have a place in qualitative research because coders are not expected to perceive data in the exact same way (Armstrong et al., 1997). Others recommend that the verification strategies, including multiple coding, as well as self-correction, is recommended for the conduct of any qualitative inquiry (Morse et al., 2002) and especially when conducting TDF-informed qualitative research (Atkins et al., 2017). In this study to improve the rigour of finings, the multiple independent coding was carried out and as a result a coding scheme was developed.

The use of a coding scheme has been suggested as an essential step in ensuring consistency in coding across transcripts (Thompson, McCaughan, Cullum, Sheldon, & Raynor, 2004). The primary purpose of the coding scheme in this study was to refine the interpretation of the TDF-based coding framework. This was done to produce an inclusive, systematic, consistent, and accurate analysis of transcripts. A general method for reaching agreement about coding data using TDF was followed (Atkins et al., 2017).

The inter-rater reliability of coding was assessed. The inter-rater reliability (Krippendorff alpha) was estimated using methods developed by Hayes & Krippendorf (2007). A Krippendorff alpha of $\alpha \geq 0.80$ is considered as an indication of high inter-rater agreement and data whose agreement falls below $\alpha < 0.667$ is usually discarded. It was planned that, if sufficient level of agreement (>80%) for each pair of coders (3 pairs: AA-KM, AA-SH, KM-SH) is not reached, to then code another two interviews.

A total of 162 (21.4%) coded quotes from the first two interviews were independently coded into 14 TDF domains by three coders – the author of the thesis (AA) and two academic supervisors (KM and SH). The proportion of the quotes that the coders agreed were as follows: AA & KM (50.90%); AA & SH (30.43%); KM & SH (32.30%). The Krippendorff alpha measure of inter-rater reliability was 0.69, 95% CI: [0.63; 0.75], with 61% chance of the alpha falling below 0.70 if an entire sample of the interviews would be coded. Since the coders did not reach an inter-rater reliability of 0.70, the disagreements in codes among AA, KM, SH were discussed over three meetings. The coding scheme was developed as the result of the meetings (Appendix P).

Another interview transcript (comprising 60 coded quotes in total) was chosen at random and independently coded into the TDF domains. The proportion of quotes that the coders agreed on was increased as follows: AA & KM improved to 81.67%; AA & SH improved to 71.67%; KM & SH improved to 63.33%. The Krippendorff alpha was 0.797 [CI: 0.72; 0.87], with a 0.5% chance of alpha falling below 0.70 if it was tested on the entire sample. Any new disagreements were discussed and integrated into the coding scheme. The remaining 13 interviews (755 quotes in total) were coded by AA using this scheme.

6.5.13.1.1.3 Generating specific belief statements

Specific belief statements about the barriers and enablers of physical activity were generated from the quotes. Specific belief statements are defined as a collection of responses with a similar underlying theme that suggest a problem and/or influence of the belief on the target behaviour (Francis et al., 2009). Strong evidence for a belief affecting the behaviour had to be present in each interview transcript, for it to be coded as a quote. The frequencies of quotes supporting a belief statement (number of quotes, k) and the number of participants (n) were calculated.

6.5.13.1.1.4 Generating causal belief statements

Each transcript was assessed on the presence of lexico-syntactic patterns used to infer causality in natural language. The TDF domains and constructs that were linked by these patterns were noted as being related to one another.

The following types of lexico-syntactic patterns inferring causality were extracted from the transcripts:

1. A causal statement about the event/experience/state indicated by the phrases such as 'because', 'since', 'as a result of', 'this led to', 'due to', etc (syntactic causal structures; Comrie, 1976);
2. A causal statement indicated by the use of causal verbs (e.g. 'resulted in', 'decreased', 'increased', 'caused', 'made');
3. A conditioning statement indicated by semantic structure such as if-then and when-then. For example, 'when I had a surgery, I became more confident in exercising'; or 'if I have ICD implanted, I would be less breathless';

4. A counterfactual statement (Roese & Olson, 1995), which include statements supporting reasoning about consequences of hypothetical but feasible situations or events that are contrary to the actual situation or event. This may involve imagining alternative (contrary to the facts) scenarios and their antecedents. For example: 'If I did not have friends who push me, I would not schedule going to the gym, I would stay home and vegetate.' Or social counterfactual: 'I know a person who never was reassured by his/her health professional in the safety of exercise after their heart attack and they do not have any motivation and do not exercise. It is the opposite for me. My doctor is very keen on me being physically active and I need his/her reassurance.' Counterfactual explanation is widely supported as a tendency in human reasoning to formulate and express perceived links between cause and effect (Tversky & Kahneman, 1974) Pearl 2003; Mandel 2005).

The descriptions of perceived cause-effect relationships between TDF domains and physical activity were extracted from the transcripts and used in building a graph that represents this causal structure.

6.5.13.1.1.5 Identifying relevant theoretical domains

The belief statements were categorised according to TDF. The relevance of the domains was evaluated by four researchers – the author of the thesis and three experts (SN; KM; SH) as follows.

Quantification: Domains were judged as likely to be relevant for changing physical activity in HF if a high relative frequency of the specific beliefs underlying the domain is present i.e. number of quotes (k) and number of participants (n).

Pervasiveness: For a belief to be considered relevant, it had to be expressed by more than two participants at least. If a specific belief has low frequency (number of quotes, k) but was mentioned by all participants it was identified as relevant to physical activity.

Differences between transcripts: The beliefs that were shared by all physically active individuals but not shared by sedentary individuals was judged as relevant.

6.5.13.1.1.6 Mapping specific beliefs onto theoretical constructs

The essence of the content to each code (i.e. quote or a parse) is recommended to be named in qualitative research (Cummingham et al., 2007). This is ought to improve the specification in the description of the qualitative findings. In this study, the individual code – belief statement – was expressed as a theoretical construct. Theoretical construct is a notion of a factor that influences behaviour and can be classified into a domain. For example, self-efficacy is a theoretical construct that has been previously discussed in Chapter 4, which may influence physical activity, and which falls into the *Beliefs about Capabilities* domain. Belief statements were mapped onto theoretical constructs. The constructs were chosen if they described each belief statement most accurately in a single term. Standardised definitions of the constructs as described by TDF (Cane et al., 2012), the APA Psychology Dictionary (American Psychological Association, 2007) were adopted. *Environmental Context and Resources* constructs were adopted from HF guidelines (NICE, 2018). This has been done to situate the findings of this study in the vast body of literature on behaviour change and HF.

6.6 Results

6.6.1 Recruitment rate

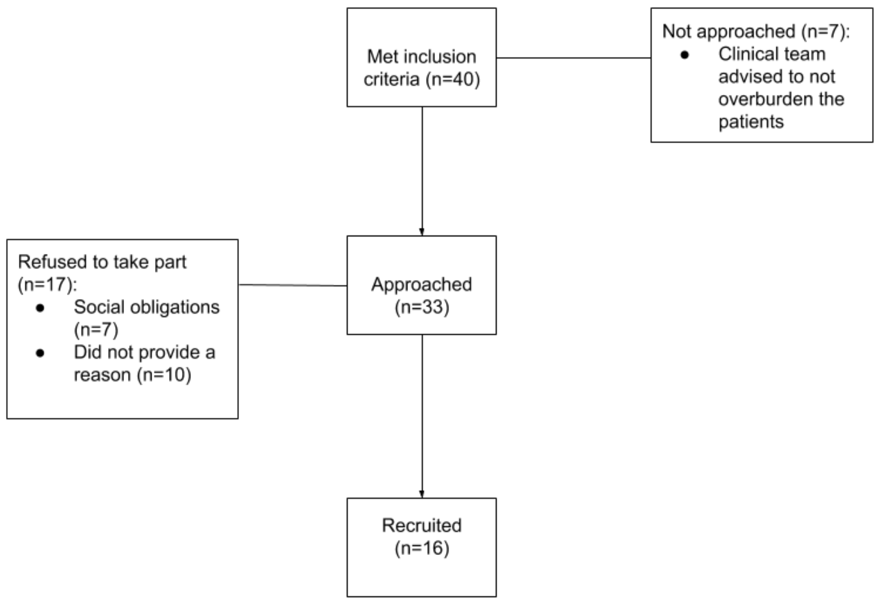

Figure 6.1. Study flow chart.

A total of 40 patients who were screened for inclusion met the inclusion criteria; of these, seven (17.5%) were not approached, because of the recommendation of their clinical team, who had concerns about their current health status and ability to participate. Thus, 33 (82.5%) were approached and invited to take part in the study.

Seven of those approached (21%) refused to take part due to social obligation (e.g. parking ticket, meeting a relative). Ten (30.3%) did not provide a reason. A total of 16 participants took part in the study. Semi-structured interviews were conducted face-to-face in a research room available at RBHT (n=6) a vacant consultancy room (n=6) and via phone (n=4).

All interviews were audio-recorded and transcribed verbatim. Interviews' duration ranged between 15.04 to 85.01 minutes (mean = 41.24, SD = 20.97). The researcher attempted to recruit as diverse (in regard to gender and ethnicity) of a sample as possible. However, fewer women attended clinical appointments, therefore fewer women were approached (33 men vs 9 women) in the first place. In addition, fewer women expressed an interest in taking part in the study - a total of five out of nine approached women refused to take part. A few individuals were from a minority ethnic background (n=4, 25%).

6.6.2 Participant characteristics

Participants' characteristics are reported in Table 6.1 . The final sample included 16 participants of a mean age of 79.19 (SD=5.15) years old, four of whom were women and 12 were men. The majority of the participants were within NYHA class III (n=10). The mean EF of the sample was 33.87 % (14.09%) . Participants were diagnosed with HF, on average, for 10.16 (SD=9.40) years and experienced 4.88 (SD=2.39) comorbidities. The most frequently reported comorbidities were: Atrial fibrillation (n=6); Arthritis (n=6); Myocardial infarction (4); Aortic stenosis (n=3); Pulmonary hypertension (n=3); and Mitral regurgitation (n=3). The total of four participants had an implantable device (i.e an implantable cardioverter-defibrillator). One participant (Participant 3) was diagnosed with clinical depression. Depression is a considerable barrier to physical activity in HF (reported in Chapter 4). Therefore, the transcript of the semi-structured interview with this participant will be contrasted to the rest of the sample in order to identify any patterns that differentiate the narrative provided by Participant 4 and others.

The participants were noticeably less frequently hospitalised (zero to three times in the past year) and have spent fewer days (mean=5, SD=6.74; median = 3 days) in hospital than the general HF population (median hospitalisation = 9 days; National HF Audit, 2018

Table 6.1. Participant Characteristics

Demographic Characteristics			**Clinical Characteristics**	
Age (mean, SD)	79.19 (5.15)		*Number of comorbidities (sample mean, SD)*	4.88 (2.39)
Gender, n (%)			*Implantable device, n (%)*	4 (25%)
Male	12 (75 %)		*HF aetiology: Non-ischemic*	8 (50%)
Female	4 (25 %)		*HF duration, years (mean, SD)*	10.16 (9.40)
Education			*LVEF, % (mean, SD)*	33.87 (14.09)
Graduate, n (%)	1 (6.25%)		*NYHA Class I*	1 (6.25%)
Undergraduate, , n (%)	3 (6.25%)		*NYHA Class II*	10 (62.5%)
GCSE/A-levels equivalent, , n (%)	10 (56.25%)		*NYHA Class III*	5 (31.25%)
No formal education, , n (%)	2 (12.50%)		*Hospitalisation frequency in past year*	
Ethnicity			*Never, , n (%)*	7 (43.75%)
British – White, n (%)	11 (68.75%)		*Once, , n (%)*	7 (43.75%)
British – Pakistani, n (%)	1 (6.25 %)		*Twice, , n (%)*	1 (6.25%)
White – Irish, n (%)	1 (6.25 %)		*Three times, , n (%)*	1 (6.25%)
White Other, n (%)	1 (6.25%)		*Hospitalisation duration, days (mean, SD)*	5 (SD=6.74)
Asian Other, n(%)	2(12.50%)			
			Most frequently taken medications	Ramipril (n =14); Bisoprolol (n=11); Valsartan (n =6)
			Medication (mean, SD)	6.94 (SD=2.17)

Note: NYHA class as assessed by a cardiology consultant or a HF-specialist nurse at the clinical assessment preceding the recruitment by 2-7 days; LVEF (%) the most recent recording in the medical notes (varied from one week up to six months)

6.6.3 The nature of physical activity behaviour

Sedentary behaviour (n=1): Participant 5 was mostly sedentary but used an exercise step and walked indoors.

Moderate physical activity (n=15): All but Participant 5 walked daily either for daily tasks or for leisure. Two participants walked for daily tasks only (Participant 3 and 4).

Vigorous physical activity (n=8): Three participants had an exercise routine (Participant 7, 11, 8); two attended a gym (Participant 2 and 1), one – a sports club (bawls; Participant 15), one – an aqua-aerobics class (Participant 1), and one participant exercised regularly using a rowing machine (Participant 16).

Habitual physical activity behaviour (n=5): Three participants never engaged in physical activity other than walking and did not change their physical activity behaviour after the first cardiac decompensation/heart attack (Participant 4, 6, 12). Two have always been physically active at vigorous-moderate level (Participant 7 and 11) and remained to be so after being diagnosed with HF. Both had an established exercise routine.

Change in physical activity because of HF (n=11): Five initiated vigorous physical activity (Participant 1, 2, 8, 15, 16) after the first cardiac decompensation/heart attack following some advice from a health professional. Five stopped engaging in any physical activity other than walking (Participant 3, 9, 10, 13, 14) after the first cardiac event (i.e. surgery, heart attack, cardiac. decompensation), which took place 10.15 (SD=9.40) years prior to the interview. One participant became sedentary (Participant 5) over an unspecified period of time after HF diagnosis.

6.6.4 Results of the TDF-based analysis

A total of 78 belief statements were produced from 16 transcripts. The corresponding constructs and the TDF domains, number of quotes supporting them, and the number of participants expressing these beliefs are described in Table 6.2.

Table 6.2. The TDF domains, constituting belief statements, corresponding constructs and their relevance to physical activity in HF

Theoretical Domains Framework and constituting belief statements	Construct	Barrier/Enabler	Number of participants (N)	Number of quotes (k)
Environmental Context and Resources			15	99
Equipment (bike; treadmill) helps me in being active	Equipment[4]	Enabler	5	16
Facilities (e.g. local council) help me in being physically active	Facilities[4]	Enabler	4	5
Group programmes help me in being physically active	Exercise-based group programmes[4]	Enabler	5	8
Implantable device		Enabler	4	12
Having an implantable device reassures me when engaging in physical activity	Implantable device[4] (enabler)	Enabler	4	9
My implantable device can harm me if I engage in physical activity	Implantable device[4] (barrier)	Barrier	2	4
My physical activity levels decreased since a major life event	Major life events[2] (barrier)	Barrier	3	3
My physical activity levels decreased since health-related event	Health-related event[2] (barrier)	Barrier	7	11
My physical activity levels increased since health-related event	Health-related event[2](enabler)	Enabler	2	4

Theoretical Domains Framework and constituting belief statements	Construct	Barrier/Enabler	Number of participants (N)	Number of quotes (k)
My physical activity levels increased since a major life event	Major life event[2] (enabler)	Enabler	1	2
Treatment	HF treatment[4]		***7***	***17***
My HF treatment (e.g. medication) helps me in engaging in physical activity	HF treatment[4]	Enabler	4	8
My HF treatment prevents me from engaging in physical activity	HF treatment[4]	Barrier	3	9
My local environment limits me in engaging in physical activity (incline (hills); crowds; traffic; pollution)	Local environment[1]	Barrier	8	20
Beliefs about Consequences Domain			15	89
Negative outcome expectancy[1]		Barrier	***10***	***37***
Physical activity brings on my symptoms (e. g. breathlessness)	Negative outcome expectancy[1]	Barrier	10	29

Theoretical Domains Framework and constituting belief statements	Construct	Barrier/Enabler	Number of participants (N)	Number of quotes (k)
Physical activities bring on my symptoms (e.g. tight chest; swollen legs; extreme fatigue)	Negative outcome expectancy[1]	Barrier	2	2
Physical activity Is dangerous because it puts my heart under strain	Risk perception[1] Concerns	Barrier	4	6
	Positive outcome expectancy[1]	Enabler	***11***	***52***
I engage in physical activity because it makes me feel more cheerful	Positive outcome expectancy[1]	Enabler	6	12
Physical activity improves my general health	Positive outcome expectancy[1]	Enabler	13	36
Physical activity improves the condition of my heart	Positive outcome expectancy[1]	Enabler	3	4
***Goal* Domain**			15	109
Engaging in physical activity is a priority for me	Goal priority[2]	Enabler	14	30

Theoretical Domains Framework and constituting belief statements	Construct	Barrier/Enabler	Number of participants (N)	Number of quotes (k)
Engaging in physical activity is (not) a priority for me	Goal priority[2]/Goal conflict	Barrier	5	8
Physical activity is important to me	Goal (behavioural)[2]	Enabler	11	22
I engage in physical activity to be able to get on with life without help from others	Outcome goal[2] (extrinsic motivation[1]: functional independence)	Enabler	9	23
I already engage in as much physical activity as I am able to	Behavioural goal[2]: capability-corresponding goal* (lack of intrinsic motivation[1])	Barrier	2	8

Theoretical Domains Framework and constituting belief statements	Construct	Barrier/Enabler	Number of participants (N)	Number of quotes (k)
I have integrated an adequate amount of physical activity into my life	Behavioural goal[2]: Goal attainment*	Enabler	7	18
***Social Influences* Domain**			11	99
I engage in physical activity because a health professional (e.g. GP, consultant, nurse, physiotherapist) has advised me to do so	Health professional's advice[4] (enabler)	Enabler	7	26
Having a reassurance from a health professional that PA is safe encourage me to exercise	Health professional's advice[4] Reassurance (Social support to reduce risk perception)*	Enabler	3	9
I limit my physical activity because a health professional (e.g. GP, nurse, physiotherapist) has advised me to not overdo it	Health professional's advice[4] (barrier)	Barrier	2	5
I would engage in physical activity if it involved being with others	Social Support (practical)/Companionship*	Enabler	5	12
I rely on other people to perform physical activity	Social support[3] (practical)	Barrier	4	6

Theoretical Domains Framework and constituting belief statements	Construct	Barrier/Enabler	Number of participants (N)	Number of quotes (k)
People who are important to me discourage me from engaging in physical activity	Social support[3] (emotional, barrier)	Barrier	5	11
People who are important to me encourage me to be physically active	Social support[3] (emotional, enabler)	Enabler	7	15
I would engage in physical activity with others if their level matched my capability	Social comparison[1](linked to self-efficacy)	Barrier	2	4

Theoretical Domains Framework and constituting belief statements	Construct	Barrier/Enabler	Number of participants (N)	Number of quotes (k)
Making plans with others encourages me to engage in physical activity	Social support (practical)[3] linked to behavioural regulation	Enabler	4	7
Other people are role models	Social modeling[1]	Enabler	3	4
***Beliefs about Capabilities* Domain**			16	73
I lack confidence in engaging in physical activity because of my heart condition	Self-efficacy[1] (Heart Condition)	Barrier	5	8
Illnesses other than HF limit my ability to engage in physical activity	Self-efficacy[1] (Comorbid Chronic Conditions)	Barrier	12	25

Theoretical Domains Framework and constituting belief statements	Construct	Barrier/Enabler	Number of participants (N)	Number of quotes (k)
My limitations to engaging in physical activity is part of getting older	Self-efficacy[1] (Aging)	Barrier	11	23
Symptoms of my HF (e.g. breathlessness; tight chest; fatigue; swollen legs) limi my ability to engage in physical activity	Self-efficacy[1] (HF Symptoms)	Barrier	5	17
***Behavioural Regulation* Domain**			14	57
I have a physical activity routine I follow	Habit	Enabler	3	9
I know when and where I will engage in physical activity over the next week	Planning[1]	Enabler	3	4
I monitor intensity and or duration of physical activity to make sure I do enougl	Self-monitoring[1] (attainment)*	Enabler	3	4
I monitor the intensity and or duration of physical activity to make sure I do no overdo it	Self-monitoring[1] (downregulation driven by risk perception) *	Barrier	2	6

Theoretical Domains Framework and constituting belief statements	Construct	Barrier/Enabler	Number of participants (N)	Number of quotes (k)
I pace my physical activity to match my physical ability	Implementation intention[1]	Enabler	10	30
When weather is bad, I engage in physical activity indoors	Implementation Intention[1]	Enabler	3	4
***Emotion* Domain**		Barrier	13	55
I enjoy engaging in physical activity	Enjoyment[1]	Enabler	9	23
I have to be in a mood to exercise	Mood[1]	Barrier	10	12
I only engage in physical activity when I am bored	Mood[1]	Barrier	1	3
I feel compelled to engage in physical activity	Impulse[1]	Enabler	3	5
When I think about engaging in physical activity, I start to worry	Worry[1]	Barrier	2	3
I am too worried about the consequences of being active	Fear of consequences[1]	Barrier	5	9
***Social Professional Role and Identity* Domain**			12	50

Theoretical Domains Framework and constituting belief statements	Construct	Barrier/Enabler	Number of participants (N)	Number of quotes (k)
Being physically active is a big part of my life	Congruence of behaviour with self[1]	Enabler	8	15
I am not an athletic person	Self-concept[1]	Barrier	3	8
I have always been an active person	Past behaviour[2]	Enabler	9	27
Memory, Attention, Decision Making Processes Domain			12	39
Engaging in physical activity is something I do automatically	Habit[1]	Enabler	5	8
Engaging in physical activity requires a lot of thought and planning	Cognitive load[1]	Barrier	12	23
I often forget to follow my physical activity routine	Memory[1]	Barrier	5	6
I get distracted from being active	Attention[1]	Barrier	2	2
***Optimism* Domain**			10	30
I am optimistic about my ability to engage in physical activity	Optimism (self-efficacy)[1]	Enabler	2	2

Theoretical Domains Framework and constituting belief statements	Construct	Barrier/Enabler	Number of participants (N)	Number of quotes (k)
I am optimistic by nature	Optimism (trait)[1]	Enabler	6	8
I am optimistic that engaging in physical activity will have positive outcomes for me	Optimism (consequences)[1]	Enabler	5	13
I am optimistic that I will engage in physical activity in the near future	Optimism (intention)[1]	Enabler	4	5
I hope to remain physically active	Hope[1]	Enabler	2	2
***Reinforcement* Domain**			9	25
I engage in physical activity because my doctor or other health professionals are pleased with me when I do	Social reward[1]	Enabler	1	1
I keep engaging in physical activity because it makes me feel better	Reinforcement[1]	Enabler	6	16
Negative consequences of PA (pain; getting out of breath) discourage me	Punishment [1]	Barrier	2	3
'I engage in physical activity because people close to me are pleased with me when I do'	Social reward[1]	Enabler	4	5

Theoretical Domains Framework and constituting belief statements	Construct	Barrier/Enabler	Number of participants (N)	Number of quotes (k)
***Intention* Domain**			8	22
I try to engage in some form of physical activity every week	Intention (stability)[2]	Enabler	5	6
I will try and engage in some strenuous physical activity in the next week	Intention[2]	Enabler	5	8
I do not intend to be active for the sake of being active	Intention (lack)[2]	Barrier	5	8
***Knowledge* Domain**			11	21
I don't know whether physical activity is good for me	Knowledge[2]	Barrier	5	6
I have learnt what physical activity is appropriate for me to engage in given my diagnosis of HF	Knowledge[2]	Enabler	8	9
I know how much physical activity I can safely do	Knowledge[2]	Enabler	4	4
I know how much physical activity I should be engaging in	Knowledge[2]	Enabler	2	2
***Skills* Domain**			7	13

Theoretical Domains Framework and constituting belief statements	**Construct**	**Barrier/Enabler**	**Number of participants (N)**	**Number of quotes (k)**
After I have been hospitalized, I had to get used to walking again (I had to relearn walking)	Learnt skill[1]	Barrier	1	2
Being shown how to perform a form of physical activity helped me to become more physically active	Demonstration of the behavior[3]	Enabler	2	3
I have been shown what physical activity to do since I was diagnosed with HF	Demonstration of the behavior[3]	Enabler	2	2
I require training to be able to perform physical activity	Learnt skill[1] (physical)	Barrier	5	6

Note 1: red – barrier; green – enabler; colour intensity(i.e. gradient) – the importance/relevance of the belief to the behaviour; 1. The definition and the construct term is adapted from APA dictionary; 2. The definition and the construct term is adapted from the TDF framework (Davies et al., 2012); 3.The definition and the term is adapted from BCTTv1; 4.The definition and the term is adapted from NICE guidelines; *The construct definition and term is not widely used and not empirically supported. The preliminary names are noted to preserve the specificity of the belief statement content.

6.6.4.1 Environmental Context and Resources

Most of the participants (n[11]=15;k= 129) expressed that *Environmental Context & Resources* played a salient role in hindering or enabling their physical activity.

The following belief statements were formulated from direct quotes:

'Having an implantable device reassures me when engaging in physical activity' (n =4; k=9)
'My physical activity has decreased since a recent major life event (e.g. retirement, death in the family, moving house)' (n=3; k=3);
'My physical activity has increased since a recent major life event (e.g. retirement, death in the family, moving house)' (n=1; k=2);
'My physical activity has decreased since a recent health-related major event (e.g. hospitalisation, surgery, heart attack)' (n=7; k=11);
'My physical activity has increased since a recent health-related major event (e.g. hospitalization, surgery, heart attack)' (n=1; k=2);
'My HF treatment (e.g. medication) helps me in engaging in physical activity' (n=4; k=8);
'My HF treatment prevents me from engaging in physical activity' (n=3; k=9);
'My local environment limits me in engaging in physical activity (incline (hills); crowds; traffic; pollution)' (n=8; k = 20).

These were mapped on to the following Environmental Context & Resources constructs:

1. Local environment;
2. HF treatment (medication and implantable devices);
3. Facilities & equipment (e.g. exercise programmes, pool);
4. Major life events.

[11] n – number of participants; k – number of quotes (used throughout the Chapter to indicate relevance and pervasiveness of the belief).

The belief statements are listed in italic (n and k are noted).

Examples of the quotes from which the belief statements were produced are summarised below, in the corresponding sections.

6.6.4.1.1 Local environment

A total of eight participants (n=8) expressed that the Local Environment influenced how active they were. Depending on several properties of the environment, it was either enabling or limiting them. Participant 4 (80 years old, female), for example, was affected by the quality of the air (pollution) in London[12]:

> *'I was walking in the countryside where the air is cleaner. When you get pollution in the atmosphere, it becomes very hard.'*

Participants, being frail and lacking balance, often expressed concerns about the safety of the environment to illustrate Participant 4:

> *'Once you are in the fields, and away from traffic it is easier [to walk], cause if you do fall down, it is usually fairly soft, you might get a bit muddy, but you would not break anything necessarily.'*

Some participants (n=3) talked about crowds as a major barrier to walking. Participant 6 (77 years old, female):

> *'or I may have a giddy turn and I have to stop, so it is OK (to walk) where I live but when you are in London and there are people pushing and shoving all the while, it is not the ideal place to be.'*

Having a space to walk or engage in physical activity prompted higher levels. Participant 15 (75 years old, male):

> *'There is nowhere to get busy (in London), well apart from the garden and the park, where I go whenever I can.'*

> *Participant 11 (83 years old, male): 'My main recreational activity is gardening. I have a large garden. About a third of an acre…which I basically look after myself. There is always something to do there…[…] the roses'*

Thus, lack of safety, polluted air and crowds limited physical activity. These properties of the environment raise concerns about safety, increase perceived risk of

[12] Quotes are reported in quotation marks in smaller font; the triple dot – long pause; double dot – short pause; […] – omitted text; [comment] – author's comment.

falling, and limit breathing. This nudged participants away from engaging in physical activity. Properties of the environment that provided safe space and enabled easy breathing, on the other hand, were appreciated and enabled an active lifestyle.

6.6.4.1.2 Facilities & equipment

A total of five participants (n=5) owned an exercise equipment at home. Three of them found having equipment helpful in promoting their physical activity. Participant 1 (80 years old, male) spoke about the benefits of an electric bike. An opportunity to tailor the setting of intensity in accordance with perceived ability setting seemed to help the participant to use it and therefore promoted physical activity:

> *'It is an electric bike, but it is not ...not... like a moped. Where you just sit on and let it drive you...you have to pedal. So you are getting exercise...and you set the amount of effort you need to put in to it...electronically...and it works' ...if I put a little bit of... erm... support...which is what this bike gives you...you know, then I can pedal up the hill easily [optimistic voice; smiles] and then we are taking conventional cycling...not a problem at all... now that movement the exercise from that that's really...I find very, very helpful.'*

> *[HF-specialist nurse] has advised I exercise. She showed them to me, and suggested we get a step...you know...You sort of step on it and step down. I do that three times a week.*

Participant 5 (76 years old, male) was given a step by a HF-nurse and found it helpful:

> *[HF-specialist nurse] has advised I exercise. She showed them to me, and suggested we get a step...you know...You sort of step on it and step down. I do that three times a week.*

Participant 16 (83 years old, male) owned a rowing machine and cared about the aesthetics and convenience:

> *I have this rowing machine in the corner, it's just the way it looks, a very small piece of furniture. It looks good and it's very convenient to use.*

Others did not find having exercise equipment a helpful long-term strategy for maintaining a physically active lifestyle. Participant 6 for example disclosed:

> *'Or maybe the treadmill, you know people I know who are doing these things? I would, as a friend, I would join them, but I am not very good at going somewhere and getting on a treadmill and doing that for 10 or 15 minutes or whatever...and getting off and coming back home.'*

Two shared that it was not a useful long-term strategy for maintaining physical activity. Participant 13 (87 years old, female):

> *'I have an exercise bike, but I must say I haven't been using it lately.'*

Overall, aesthetically pleasing, convenient, in-house equipment that has an inbuilt mechanism to regulate the intensity at which it can be used is a useful strategy according to the participants. This is consistent with the line of work that resulted in the Typology of Interventions in Proximal Physical Micro-environments to change behaviour (TIPPME; (Hollands et al., 2017, 2013). TIPPME prescribes that the availability of an object, as well as tailoring of functionality, and presentation are key in how effectively an object can be used to change behaviour.

6.6.4.1.3 Group exercise programmes

Participants reported that being able to attend group exercise programmes and local sports clubs was an important resource in initiating an active lifestyle (n=5; k=8). In addition, having completed a group exercise programme promoted self-efficacy (*Beliefs about Capabilities*). To illustrate, Participant 1 (80 years old, male) highlighted:

> *'Actually, one thing that I did was going to cardiac rehab. To be honest, that was...it was like ...'Oh God! I am too weak to do this', and they would say: 'No, you are not, you can walk up that 5 yards there, can't you?' ... Ok, I can do that'.*

Group programmes helped to establish a social network and provided emotional social support (*Social Influences*) as well as the support in forming plans (*Behavioural Regulation*), as Participant 15 (75 years old, male) reported:

> *'Being part of the club [bowls club], I know what days we play and when to come we just do it twice a week. Sometimes a bit more.*

Others expressed that the level of intensity of the group did not match their ability and therefore, was not of any use to them. For example, Participant 16 (83 years old, male) expressed:

> *'Classes are fine. As you start, as you go, you have to go at the lowest ...lowest pace as the slowest member... and I don't find classes work. I prefer to take instruction and then carry it out, demonstrate that I can do it and then do it by myself.'*

Therefore, group programmes improved *Behavioural Regulation*, resulting in the formation of positive *Beliefs about Capabilities*. However, this was achieved only when the activities were performed at a preferred intensity.

6.6.4.1.4 Implantable devices

Four participants had the following implantable devices fitted: implantable cardioverter defibrillator (n=1), conventional pacemaker (n=2), and biventricular pacemaker (n=1). An implantable device was seen as a barrier for some (n = 2) and an enabler for others (n = 4). The devices were very salient to these participants and had a large influence on their physical activity as reflected in the length to which they were described in each interview (n=4; k=12).

Counterintuitively, two participants expressed their concern about implantable devices and reported these as a barrier to engaging in physical activity. The devices were out of the participants' control and, therefore, they worried about an unexpected fault with a device that could happen during physical exertion. As Participant 15 (75 years old, male) reported:

> *'Also, with my pacemaker...I have to be careful. I have to make sure I do not overdo it [physical activity]. You know? ...they tell me...the more you do you use up the battery. This is my second one I had it for six years. The first one I had for just over 3 years...I think you have to be careful about how much you do things.'*

While others reported that having a device was a source of reassurance, which protected them from adverse events and boosted their confidence in engaging in physical activity, Participant 12 (81 years old, male):

> *They have tweaked my pacemaker several times and that has improved things (gardening and walking mentioned earlier in the interview).*

One participant expressed that the reassurance provided by the device both enabled and hindered his physical activity. Participant 1 (80 years old, male):

> *' And of course, since I had the ICD implanted it became much more relaxed. Because they know that these devices will recover you whatever the situation you are presented with. It is a reassurance factor; it is quite astounding. That psychological bit, you know that you are not doing yourself any harm [by exercising].'*

Participant 1, however, later in the interview reported that having the 'failsafe' device and knowing that this will prevent negative outcomes of HF discouraged physical activity. The participant expressed perceived lack of necessity to exercise, given that the device is there to improve cardiac performance:

> *'The device that I got in there is going to work regardless of whether I do any exercise or not...let's say I didn't do any exercise... if I've decided to become a cabbage and lay in front of a television...you know and eating fat... the chances are...well, chances, it wouldn't be doing me any good right? but the implanted defibrillator is going to rescue me from death... it is almost bad knowledge to have that... I have this failsafe thing implanted in me.'*

Participants held a perception that the device will '*keep the heart going'* in case of any failure of their heart at exertion. Two participants reported that since they were given the device, they feel sufficiently more physically fit and, therefore, are confident in engaging in physical activity.

It appears that there are individual differences in the beliefs about the implantable devices and the safety of physical activity when having one surgically fitted. For some, it was a large source of concern about the safety of the heart and for others, it was a source of reassurance in physical activity not being harmful to the heart, when knowing that the device will optimise cardiac performance.

6.6.4.1.5 Major event

Cardiac events (heart attack, acute HF, HF decompensation, cardiac surgery) resulted in an overall lifestyle change in the long-term for most participants (n=9; 14).

Participants were divided in their perception of the major event's influence on physical activity. Some participants reported that the event encouraged them to lead a physically active lifestyle (physical activity). Others reduced their levels of physical activity.

When looking at what may have contributed to this polar impact of a major health-related event, it was overall evident from the interviews that an optimistic outlook on life and having resources and social support readily available would encourage the perception of the major life event as promoting their physical activity levels, for example:

> *Participant 1 (80 years old, male): 'So, the heart attack was a trigger, the catalyst for change [in participant's lifestyle which participant described earlier in the interview]'.*

Participant 8 (70 years old, male): *When I had the surgery [bypass surgery] I became fit.*

When asked about when the participant started rowing, Participant 16 (83 years old, male) replied:

> *'Only recently...but it was not possible... I do it when...at the moment...it took a long time... more than a week after I got out [out of hospital after the decompensation of HF[..]*
>
> *'I wasn't physically active before I had my heart attack. This is new. It only came about, really, as a consequence of a heart attack in 2001'.*

In summary, a cardiac event and the following hospitalisation, presented a threat to participants health and initiated behaviour change, including physical activity, by triggering a reflection on the status quo – the current state of health management and heath. Participants referred to heart attack as ‘a catalyst for change’ and a ‘trigger to change’ when talking about their lifestyle.

Participant 9 Had a pessimistic outlook and lacked social support and reported negative emotional changes (depression).

Other participants reported that a major cardiac event forced them to limit physical activity:

> *Participant 9 (74 years old, male):* ‘*I was walking one mile every day. When I was...before the bypass... 18 years ago I had bypass... but when I do, I walk very slowly. I don’t do any exercise, walking for the past five..four years, nothing. Because: hospital, hospital, hospital...sometimes heart is not working properly, sometimes bypass not working.’*

Participant 10 (91 years old, male) also shared that he abolished moderate and vigorous activity after a heart operation:

> *‘When the pain started. After my first heart operation it lasted nearly 20 years... the last year I probably had a heart attack. I had an attack of some kind’....’why did I stop [walking long distances mentioned earlier in the interview]? Hm...oh, cause of an operation I had... one of the heart operation...they said to be careful the first month...and fundamentally, when you stop you don’t start again...at my age’.*

For another participant a surgery resulted in a short-term pause in activities, but participant intended to restart a more active lifestyles once she recovers:

> *‘Participant 13 (87 years old, female):* ‘*I mean it is only a matter of weeks since I had this major surgery...I had an operation three years before that. But when this treatment is done and over with, I should be down to being monitored. So, then I can really think about it [joining a local council sports club and walking more]”*

Participants are medically advised to reduce activities during the first months after the surgery or other cardiac operations. This seems to initiate habitual sedentary behaviour, especially in older age, as perceived by participants. Undergoing a major invasive procedure also seems to lead to the formation of concerns about the safety of physical activity. Whereby, the participants would consider physical activity, only when they are closely monitored by the clinical team.

Major life-related events also were mentioned as a trigger to physical activity change. Some participants increased their activity (n=1; k=2). To illustrate, for example, Participant 11 (83 years old, male) shared that they started having an exercise routine since they have retired:

> *'Certainly, since I have retired. Getting up in the morning to go to work, I didn't have time to do it, when I was a commuter. It is certainly since I have been retired.'*

Retirement provided an opportunity and time for integrating an exercise routine for Participant 11. Other participants reduced their physical activity since a major life event (n=3; k=3). Participant 4, for example (80 years old, female) shared:

> *'I worked for 20 or 30 years, I think. I used to get pretty busy...I used to have a little office in a new building and there will be a walk rail...all the way around...Quite a big square, which is undercover, and periodically, I would get up and walk around the corridors (laughs). And now I don't have that. It was a long time ago.'*

A shift in lifestyle associated with retirement lead to settling into a habit either of sedentary behaviour, like described by Participant 4, or a habit of performing structured exercise in the mornings, like reported by Participant 11. The perception of the major life event seems to vary among participants between either being a strong enabler of physical activity or an equally strong barrier.

Overall, participants formulated physical activity beliefs about local environment, facilities, implantable devices, group programmes, and major events. These beliefs acted as both, a barrier or an enabler. The differences are explored in Appendix Q.

6.6.4.2 Goal

A total of 15 participants pervasively (number of quotes, k=109) expressed beliefs that can be classified as Goal. These beliefs included:

'Engaging in physical activity is a priority for me' expressed by 14 participants (n=14) in 30 quotes (k=30);

'I engage in physical activity to be able to get on with life without help from others' expressed by nine participants (n=9) in 23 quotes (k=23);
'I already engage in as much physical activity as I am able to' expressed by two participants (n=2) in eight quotes (k=8);
'I have integrated an adequate amount of physical activity into my life'. expressed by seven participants (n=7) in eighteen quotes (k=18).

These belief statements were conceptualised as the following constructs, respectively:

goal priority;
outcome goal (extrinsic motivation);
behavioural goal: capability-corresponding goal (lack of intrinsic motivation);
behavioural goal: goal attainment (intrinsic motivation).

As can be judged from parses below, these four types of goal beliefs are the instances of intrinsic and extrinsic motivation to engage in physical activity. Participants often listed a personal outcome goal of engaging in physical activity – remaining self-sufficient. This outcome goal was a strong enabler of the behaviour even in the absence of perceived ability.

On the other hand, those who perceived a lack of ability to engage in physical activity, may have not held a strong intrinsic motivation to do so, and, also, did not prioritise physical activity over other hobbies. Whereas those who pushed themselves and prioritised exercising formed strong intrinsic motivation.

6.6.4.2.1 Goal priority

Participants prioritised physical activity to a varied degree. Participant 1, 4, and 6 lacked an intrinsic motivation to engage in physical activity. They preferred to only engage in activities like walking and avoid other types of physical activity:

> *Participant 1 (80 years old, male): 'Oh really I can't be bothered to go out' [chuckles] and it is raining, and I wasn't going ...erm... I would rather paint a picture.*

Participant 4 (80 years old, female): 'If I get the opportunity I will go for a walk, if I got duties that need attending to, then I will try to do them in times which don't matter, in the afternoon or evening and to settle down'.

Participant 6 (77 years old, female): 'Well...I know walking is a solitary experience, I spent a lot of time on my own...So, why would I go outside? This is how I look at it, why would I go outside on my own to walk around, when I am far happier being on my own in doors with a book.'

The goal priority seems to be affected by participants' self-identity. This is further explored in the Appendix Q.

6.6.4.2.2 Outcome goal

A total of nine participants (n=9) also consistently (number of quotes, k = 23) shared an extrinsic goal for being physically active (Outcome Goal). This goal involved remaining or regaining functional independence, characterised as '*enabling life*', something that is done '*to be independent*' (Participant 11, 83 years old, male). For example, Participant 2 (76 years old, male):

I want to be self-sufficient still, I don't want to rely on other people. So, staying fit is important to me...

Another participant, when asked about how his family influences his physical activity, Participant 10 (91 years old, Male) shared:

'They are helpful... I suppose yes they are very helpful...four grandchildren, who I see very often and my daughter who I see often... they are being helpful...but after all these years I'm trying to avoid getting help...dependent is a terrible thing to be...So, I say: 'No, I will do it myself' [grumpy voice]... to stay independent.'

Thus, functional independence served as an extrinsic motivation to engage in physical activity by being an appealing and important outcome goal of physical activity. Extrinsic motivation, in the context of behaviour change theories, is conceptualised as part of self-determination theory (Deci & Ryan, 1981) and is defined as: an externally sources of incentive to perform a behaviour, based on the expected reward or punishment (American Psychological Association Dictionary, 2018).

6.6.4.2.3 Behavioural goal

Seven participants mentioned the amount, duration or intensity of physical activity they aim to engage in (k =25). Participants gravitated to two opposite beliefs about their behavioural goals: 1) the importance of pushing one's limits (n =7; k = 18); and ensuring they do not exceed their limits, beyond their ability(n = 2; k = 8).

Participants felt they already do as much as they should and are physically able to:

> *Participant 1 (80 years old, male): 'I don't do it quickly, but it is enough.'*
>
> *Participant 4 (80 years old, female): 'At the moment I am alright, as long as I keep within recommendations.. or more or less...'*
>
> *Participant 8 (70 years old, male): 'So, this is what I do [summarising bowls, walking and exercise routine] and I think it suits me and I'm happy to do that I can't do more than that.'*

While some shared a goal to engage in maximally possible physical activity, that they physically can perform (Goal Attainment). For example. Participant 16 expressed:

> *'Now I will do it every day and if I can twice a day, to the point it feels good. I'm going to build up with it to the point where it feels good. [...] You take everything to the edge until it ...and you know all exercise should begin to hurt and that's when you stop...'*

Behavioural goal was guided by perceived capability, intrinsic motivation to push oneself and how important physical activity is to them in comparison to other activities and hobbies (goal priority). Participant's' physical activity was driven by two types of goals: outcome goal and behavioural goal. An outcome goal is a desired target outcome (Davies et al., 2012). Outcome goal described by participants of this study was a desired functional independence.

6.6.4.3 Social Influences

Social influences were described by 11 participants (n=11; k = 99) and grouped into the following beliefs:

'I engage in physical activity because a health professional (e.g. GP, consultant, nurse, physiotherapist) has advised me to do so' (n = 7; k = 26);
'Having a reassurance from a health professional that PA is safe, encourages me to exercise' (n = 3; k = 9);
'I limit my physical activity because a health professional' (e.g. GP, consultant, nurse, physiotherapist) has advised me to not overdo it' (n = 2; k = 5);
'I would engage in physical activity if it involved being with others' (n = 5; k = 12);
'I rely on other people to perform physical activity' (n =2; k = 3)
'People who are important to me encourage me to be physically active' (n = 7; k = 15)
'I would exercise with others if their level matched my capability' (n=2; k=4);
'People who are important to me discourage me from engaging in physical activity' (n = 3; k = 9)
'Others are role models' (n=3; k=4)

These were summarised into the following constructs:

1. Health professional advice;
2. Companionship – Loneliness;
3. Social comparison;
4. Emotional and practical social support (enabler);
5. Social support (barrier);
6. Social modelling.

6.6.4.3.1 Clinical advice

Seven (n = 7; k = 26) participants engaged in physical activity because a health professional advised them to do so. To illustrate, Participant 5 was supported in performing an exercise that was prescribed to him by HF specialist nurse:

> *(HF-specialist nurse) check on me, and reminds I have to do this exercise and my wife makes sure I do them. See, my consultant ***** told me I have to walk and move as much as I can. So, he told me I should stand up now and then and walk around the flat, so I do that. I get up occasionally several times a day and walk to the kitchen and back and around the house.*

Similarly, Participant 7 was advised by the cardiology consultant:

> *Participant 7: And have you received any advice on how much you should do from this hospital. Participant7: Well I think you know*

*when I first saw Dr *** we discussed things and he said to keep active.*

Clinical advice also was a great source of reassurance that mitigated the perceived risks associated with physical activity:

> *Participant 1: You look up to professional and you need that reassurance to say: 'what I am doing now, is not going to impact on my long-term health'; 'is it the right thing to do?' and if the answer comes back from a professional you trust, and I have implicit trust, explicit trust as well, in my consultant...then if she says: 'that's a good thing to do', then I will do it*

Only two participants reported that they were advised to curb their physical activity level.

6.6.4.3.2 Social support (enabler)

Five participants would engage in physical activity only when with others because it increased their sense of safety and reduced perceived risks:

> *Participant 13: When I am with my daughter, I am less nervous and I am able to walk further... because she was there...and I walked very slowly but I did walk all the way and I was very pleased with myself, because I felt I have achieved something.*

Or for a company, which was coded as social support

> *What would help you to do more? Partcipant6: Probably walking with somebody else, when you are walking on your own or me...when i am walking on my own, you have to be motivated to get yourself out of the chair but if I know a friend was coming around then yes. I would then go and I wouldn't think twice about it.*
>
> *Interviewer: What is it about company that makes you want to..? Partcipant6: I spent a lot of time on my own, I live alone...So, being in somebody else's company for a while is very refreshing. Interviewer: And that would help you to be active? Partcipant6: Yes, yes! You know I've been on to a thing called the UTA which is the University of the Third Age where you know for people over about 55 where you get together and you do activities and a learning program, right? Yes. So, you've got to keep in contact with people as well, I think*

Participant 8 engaged in physical activity and enjoyed engaging in physical activity in a social context that was provided by a Fitbit, including comparison and encouragement:

> *Participant 8: I had Fitbit… it is five of us (who got Fitbit together), my friend and family… I was the third to have this. My daughter and son got it later… so when I first heard about this, I was very happy to have one once they explained to me what this does.*

6.6.4.3.3 Capability and social comparison

However, an additional condition was needed for another two participants. They preferred for people to walk at the same pace as them, and if a group (i.e. a walking group) had a greater physical capacity than them, they felt discouraged from attending it:

> *Participant 2: and I used to run a walking group[…] And now I don't really do walking with the guys, unless they do flat walks, you know, along the coast.*

> *Partcipant 6: Well let me say there is no one I could walk with, who would be a at my pace...and wouldn't be interested in walking half a mile...they DO do walk but they would be interested in walking further and quicker than I do. So, I would be a liability to them.*

In other cases, participants needed reminders from their social circle:

> *Participant 2: I think if I didn't have friends and didn't schedule…I might have vegetated and sit a bit too much…it is important to have friends you can do things with… It [the stationary bike at home] would help me I am sure, but there is no motivation for me to use it [the stationary bike at home], but if my friends came around and said oh we will do this each day, that would be fine. Alright?*

6.6.4.3.4 Social support (barrier)

Five participants reported that friends and family discouraged physical activity. The family members of Participant 1, 4, 12, 2 were very protective and attempted to shield participants from engaging in daily tasks because they felt it was unsafe:

> *Participant 1: Well I am not doing as much as I'd hoped to be honest, largely because my wife is very nervous about me going on*

> *the road[...]for God sake, it is only three miles into a local town but (imitating wife): 'Oh God it is on the road, you will get knocked off'. Interviewer: Does she stop you from going then? Participant1: Well, stop is a wrong word...you know what I mean, but ...it is the give and take of a marriage. So, you say: 'ok Love, I will not do it this time.'*

> *Participant 4: [Your family, do they talk about how much you should move around?] No, I don't think they do. Actually, they try to persuade me to sit down more.*

> *Participant 13: No, my daughter always tells me that I do too much. She was very annoyed when she came. [and saw] When I cut the grass and tided the garden.*

Most of these participants (Participant 1, 2, 12) resisted whenever they could. To illustrate:

> *Participant 2: My daughter says 'dad, you shouldn't be doing this and that'. I say: 'go away' (laughs). She says I am getting old and I shouldn't be doing this, and I should get somebody in. No (laughs). She thinks I am mad.*

6.6.4.3.5 Social modelling

Participant 7 who established a physical activity habit, including an exercise routine, reported that her parent engaged in physical activity too. She perceived her family as active people which had an impact on her behaviour, when asked what helps her lead an active lifestyle she said:

> *Participant 7: You know as I said my parents were active, we were active my daughter is now active and granddaughter. Oh, we've always been an active family..*

Participant 2 followed a positive example of his friends:

> *Participant 2: [You said you go to the gym...what motivates you to go?] Some of my mates go...and Erm...So...[pause; Interviewer: Is it a social thing then?] Yeah it is really, I copy after them (smiles)...*

Participant 15 was guided by social examples as follows:

> *Participant 15: [...]my friend next door, he has dementia, he doesn't remember things as much... [...] And he had hip replacement. Some people like that they gave up. I have other friends who did not give up, and they have a lot of medical problems. So, I learnt from them – you got to try and do your best,*

as much as you can. [Interviewer: I see, so other people are a positive example for you?] Yes. Older friends they are marvellous in so many ways and they had to get on with life. When I got to their age, I learnt from them you got to do your best.

6.6.4.4 Beliefs about Consequences

Beliefs about Consequences shaped physical activity in a total of 15 participants (n=15), who have highlighted the relevance of this domain in a total of 89 quotes (k=89). These quotes were summarised into the following belief statements:

'Physical activity brings on my symptoms, e.g. breathlessness (n = 10; k = 29);
'Physical activity brings on my symptoms e.g. tight-chest; swollen legs; extreme fatigue' (n=2; k=2);
'Physical activity Is dangerous because it puts my heart under strain' (n = 4; k= 6);
'I engage in physical activity because it makes me feel more cheerful' (n = 6; k = 12);
'Physical activity improves my general health' (n =13; k= 36);
'Physical activity improves the condition of my heart' (n = 3; k = 4).

These have been mapped to on the following existing behaviour change theory constructs:

1. Negative outcome expectancy (n=10; k = 37);
2. Risk perception (n = 4; k =6);
3. Positive outcome expectancy (n =11; k =52).

Participants engaged in physical activity to a greater extent when they held strong positive expectations of what would happen if they engage in physical activity. On the other hand, these participants who held negative expectations about physical activity and those who perceived physical activity to be a risk, were hesitant to engage in physical activity.

6.6.4.4.1 Negative outcome expectancies

Participants avoided engaging in physical activity to avoid an onset of breathlessness (n=7; k=20), tight chest (n=2; k=4), swollen legs (n=1; k=1), pain (n=1; k=3) and fatigue (n=3; k=4).

Getting out of breath was a negative expectancy that was most frequently shared by the participant (n = 10; k = 29). This expectation resulted in an attempt to reduce the intensity of physical activity, as illustrated by a quote from Participant 7 (71, female):

> *'I... sometimes if I hurry too much or going up a hill, I will get a bit short of breath. But I always...I pace myself more at home, which means if I'm in the middle of, say, cleaning or hoovering the house, I may have to sit down a bit more.'*

Participant 11 avoided prolonged physical activity: *'…any persistent walking or if I ought to go up and down the stairs several times..several times in succession I would become breathless and tired.'*

Breathlessness could also result in complete cessation of physical activity, as Participant 13 expressed: '*When I get out of breath, I try to rest'.* Similarly, Participant 6 avoided any physical activity that involved more effort due to breathlessness: *'Because it is more of an effort, I get breathless more, not as quickly, but I do get breathless.'* Participant 8, when asked what stops him said: '*Oh, breathing! Then I shouldn't do it then…*'

However, some participants differentiated the degrees of breathlessness and not all degrees were perceived as a dangerous symptom. This helped their initial engagement in physical activity. Participant 1, for example, carried on an activity despite the expectation of getting out of breath: '*I don't feel as nearly as breathless or in pain as I thought I would be… that just builds on and I just carry on*.' Participant 1, shared that he does experience the uncomfortable somatic sensation of being out of breath, but added that he recognises that it gets better over time:

> *'if you start immediately running... Oh, Gosh! (imitates breathlessness, places a hand on the chest) you get out of breath*

but after a minute or so and you just pull back a bit ...I'm just going to take easier for a minute or so...You are walking, climbing up the hill and if you are not up to the speed yet, it becomes a problem. Once you get through that you don't get out of breath' (Participant 1).

Participant 1 therefore had a chance to increase his exercise capacity which reduced breathlessness in the future.

Other symptoms were often mentioned in parsing when talking about breathlessness. Participants also described that they symptoms of swollen legs pain, and fatigue, For example:

Participant 10: 'Eventually I would probably collapse...but...it gets bad enough for me I have to sit down... and do some heavy puffing for a while...and it aches and your legs...and then it stops, and you start again.'

Participant 9: 'I know there are some advantages....but I can't, the shortness of breath, very week, I am feeling.'

Participant 10: 'Well, as I said, there is no point in giving yourself pain... if you start doing something...and it is painful...and you stop and you start again and stop and start again and you have done what you wanted to do by that time.'

Also, the perception of symptoms of tight chest was poorly discriminated from getting out of breath and overtook the participant both at once. For example:

Participant 10: 'I get breathless...not exactly...but it tightens up (demonstrates tightening with a fist around his chest), and your legs get heavier...and tighten up and my chest...and I puff for two or three minutes'.

6.6.4.4.2 Risk perception

Two sedentary participants believed that too much activity puts their heart under strain and avoided engaging in activities. However, it was not expressed as a negative outcome but rather as a perceived risk given the nature of physical activity.

One participant (Participant 4, 80 years old, female) perceived individual risk susceptibility due to the comorbidity they had - asthma:

> *'I think if you...the asthma gets worse, partially because you are doing more, and causes you, I think that must cause a strain on the heart. So, if you work backwards and try to stop the strain on the heart by not being so quite active, you will feel better asthma-wise, and that might have a beneficial effect on the heart.'*

Participant 10, similarly expressed a perceived risk of physical activity – hospitalisation:

> *I want to go on...but why should I give myself a lot of pain...and put myself in danger, when stopping that would stop as well...if it kept on going I suppose I would be ringing 999 and would be taken off to a hospital...once you get to a hospital, they want to keep you there often*

6.6.4.4.3 Positive outcome expectancies

> *'I like to be happy and I only found ...it is... if I do this [exercise] I remain happy! and you know it gives me...you know. Cheers me up.'*

Positive outcome expectancies included an anticipation that physical activity will bring about better mood; general health or improve the condition of the heart. A total of twelve participants emphasised the benefits of physical activity for their general health and reported that as one of the major outcome expectancies that encourages them to engage in physical activity. Participant 4 for example, put it as follows:

> *'We would walk around beaches and do quite a lot of walking. I used to come home after three weeks, absolutely glowing and was feeling on top of the world and could conquer anything, you know.'*

Six participants reported that their mood improved following physical activity and that this belief also was a strong driver of the behaviour. For example, Participant 16 described the uplifting effect of exercise:

> *Participant 16: 'This exercise, like all exercise has a very pleasant and nice after-effect...it invigorates you...'*

Participant 4 spoke about the improvement in mood she used to experience earlier in life:

So, when you walk it makes you feel better? Participant4: Yes, it does it helps me to breathe better. It helps your blood to circulate better, which carries oxygen...I think it gives you a better feeling of well-being generally.'

However, did not discuss the outcome expectancies she has in present time and shared the above more as a memory than present enabler.

A belief that physical activity improves the condition of their heart was expressed by three participants. To illustrate, Participant 1 expressed:

'As it turns out it [cycling] is also damn good for the heart.'

Similarly, Participant 4 stated*:*

'I am not showing any symptoms of my heart condition and I think it is because I have been doing all these things [cycling using e-bike, aqua-aerobics and walking], When I walk more, I feel better, my circulation improves.'

Those participants who held more positive outcome expectancies listed fewer negative outcomes. In addition, they would often talk about the lack of negative outcome expectancies. Participant 1, for example, described the very first instance where he overcame his negative predictions by engaging in physical activity despite the negative expectancies he might have had before:

Participant 1: 'ah! I have done some exercise – good'...it is because you actually physically feel good, 'oh that's quite good'..I don't feel as nearly as breathless or in pain as I thought I would be...'

Participant 8 when prompted to describe advantages and disadvantages of physical activity responded with a list of several advantages, While adding that he does not seem to hold any negative expectancies:

'Advantages – Yes! Many advantages, makes me happy makes me it makes me fit and makes you... to... look forward to tomorrow, the day after tomorrow, and I have lots of plans in my calendar to reach those goals, to see what I have in my calendar. But no disadvantages.'

In summary, the participants formed a number of *Beliefs about Consequences* about physical activity. This concerned their health, mood and heart condition, as well as symptom onset, and hospitalisation due to cardiac condition. There were between-participant differences that may have given rise to whether positive or negative expectancies were formed. These differences are described in Appendix Q.

6.6.4.5 Beliefs about Capabilities

All participants (n=16, k=73) expressed a low perceived capability to engage in physical activity. This was concerning the performance of physical activity, either at certain modes (e.g. running, gym), high intensity, or in large amounts. Some have said they confined the mode of physical activity they engage in:

> *'I walk. Now, this is my ability. I cannot do more than this. I cannot go to the gym and I can't run... even when I started to run a bit.. I can't run because of my heart.'*

Others reported they limit the intensity:

> *Participant 14 (77 years old, male): Today when I was on the flat, if it is completely flat and I walk slowly, I have to walk half-pace, half speed. I am restricted at the moment in being. I am inactive...and restricted in what I can do.*

And some reduced the amount of physical activity

> *Participant 5 (76 years old, male): I do not really move around that much. I can't really do that much...*

The Beliefs about Capabilities elicited from the quotes provided by the participants are summarised in the following belief statements:

'I lack confidence in engaging in physical activity because of my heart condition' expressed by four participants (n = 5) in six quotes (k = 8);
'Illnesses other than HF limit my ability to engage in physical activity' (n = 12; k = 25);
'My limitations to engaging in physical activity is part of getting older' (n = 11; k = 23).
'Symptoms of my HF (e.g. breathlessness; tight chest; fatigue; swollen legs) limit my ability to engage in physical activity' (n=5 ; k =17).

Self-efficacy was hindered by actual (NYHA class reported in medical notes and judged from visual assessment by the consultant) and perceived limitations reported by the participants throughout the interviews. These perceived limitations include:

1. Comorbid chronic conditions (n = 12; k = 25)
2. Aging (n = 11; k = 23)
3. HF symptoms (n=5 ; k =17)
4. Heart condition (n=5; k = 8)

The examples and illustrative quotes are provided below in the corresponding subsections.

6.6.4.5.1 Comorbidity-related self-efficacy

All participants experienced multi-morbidity, as evident from their medical records. A total of twelve participants reported that a particular comorbidity limited their physical activity. Self-efficacy was hampered by comorbidities such as Atrial Fibrillation (n = 6), Arthritis (n=3), COPD (n=2), Asthma (n= 2) Infection (n=1), Polymyalgia Rheumatica (n=1) and Hip Replacement (n=1). Atrial Fibrillation and hypertension reduced perceived ability to engage in physical activity as a result of uncertainty about the condition and symptoms experienced during physical activity that worried the participants. To illustrate, Participant 2 (male, 77 yrs.) expressed:

> *'Yes! I don't feel capable of doing [exercising that was discussed previously]...I don't know what is going on inside my body. Especially with atrial fibrillation... I don't know...it is always a little worry in the background.'*

Arthritis, Asthma, COPD discouraged participants in being physically active due to experienced symptoms of pain and breathlessness, which resulted in lack of perceived ability to exercise. Participant 1 (80 years old, male) for example:

> *..a lot of it is geared around this blooming arthritis... I need to find ways in which I can move limbs but without putting too much pressure on my hip.*

Participant 10 (91 years old, male), when asked about his confidence to walk:

> *No, my knees ...well, I got arthritis...so it is painful...walking.*

Participant 4 (80 years old, female) also expressed their concerns about the onset of symptoms, triggered by physical activity:

> *I try to protect asthma, I learnt when it is not a good day to push myself hard, and ease off; days I feel fit, then I do more... I look forward to it. So, I have learnt to live by my shortcomings, I think.*

Participant 4 also, as can be seen in the quote above, seems to have 'learnt' not 'to push' herself on some days; and 'learned' her physical limits. This indicates learnt behaviour – physical activity avoidance – because of repeated symptom onset following any form of physical activity. The comorbidity symptoms also lead to a 'learnt' lack of self-efficacy, as a result of the experienced symptoms. In summary, self-efficacy was reduced because of experienced symptoms of comorbid conditions, as well as concerns about the safety of physical activity given the comorbidity (e.g. Atrial Fibrillation). Lack of perceived self-efficacy has been learned through repeated experience of symptoms.

6.6.4.5.2 Aging and age-related self-efficacy

An overwhelming majority (11 out of 16), when prompted about the barriers to physical activity, listed age-related physiological changes and their debilitating role in physical activity self-efficacy and performance. For example, when asked what would help him to walk more, Participant 3 (80 years old, male) shared:

> *I don't think at my age you can think about that.*

The expected physical activity engagement given the old age counteracted the lifestyle advice received from a health professionals (*Knowledge*):

> *'It is all very nice to give instructions to your patients... but this is not the doctor's idea... because the guy of 26 or 27 can do an hour. They are fit...but they can't expect me I am 80... they can't expect me to do that... I know and they know my possibilities.'*

Often, age-related Beliefs about Capabilities did not completely eradicate a physically active lifestyle, however, did limit the intensity and amount of physical activity:

> *Participant 4 (80 years old, female): 'So, age is catching up with this in some respect...and I am 80 years old now...But I don't feel that I have lost any of my ability to be active. But perhaps I am not active when I get the opportunity and not at the speed I used to be. I have to slow down a little bit.'*

Thus, age was reported to have a negative influence on *self-efficacy*, where it reduced *Intention*, counteracted clinical advice on the benefits of physical activity (*Social Influences, Knowledge*) and also gave rise to the lack of participants' identification of physical activity as appropriate given their age *(Social Professional Role and Identity: self-identity).*

Participants 7, 2, 11, 15, and 16, reported age-related limitations to perceived ability to be physically active. However, they also described a set of attitudes, goals and strategies that counteracted the influence of age-related limitations. Participant 7 (71, female) for example, while admitting that there are types of activities she cannot perform (aerobics), she still engaged in activities that were compatible with physiological changes due to age – swimming and walking:

> *Participant 7 (71, female): [what stopped you?]. Age. Aerobics is really for younger people [...].*

Similarly, Participant 2 avoided walking uphill, however, still would engage in gardening and walking on flat surfaces. Participant 2:

> *I am still very active. Yesterday, I was actually climbing trees, and I am 77 years old. And doing hedges and you know gardening. [...] I walk for miles on the flat but any incline starts giving me problems.*

Participant 11, who habitually performed an exercise routine every morning, curtailed his activities to suit the change in the age-related capacity. He may not have been engaging in long walks, but would still remain active otherwise '*within the limitations of old age'*:

> *Things that I am too old to do, reluctantly, I get someone else to do for me. Well, I rather do it myself. [...] [Would you say physical activity is a big part of your life?] Participant11: Oh yes, within the limitations of old age. Clearly at 83 I can't do what I could at 43 or 63...for that matter. [..]I no longer go for very long walks. I still .. I still do but most of the time I walk, rather than use the car. But my days of doing long walks like walk ..tracking in New Zealand are over but one would expect that at 83.*

Participant 15 acknowledged the limitations of his older age, but adapted a strategy to pace his activities to meet this limitation:

> *Participant 15: Yes, as I said older people like me with heart problems.. sometimes you get tired and I know when to...I think: 'Oh, ok…now I got to stop and have a rest'. And then maybe two hours later …to carry on…sometimes three hours, depends on what I am doing, either gardening, DIY or exercise. […]as people get older, they know how far they can go and that's what I do.*

Participant 165 and Participant 16, had a strong belief, that can be described as *'carrying on'* despite the limitations of old age:

> *Participant 15: Well, obviously, in my opinion, when people get older it all slows down a little bit, which is alright you have to face the facts...and carry on doing things you can as much as you can…*

Similarly, Participant 16 expressed a strong intention to do *'the best you can'*:

> *Participant 16: There's a big difference between 18 and 83, and then you don't have... you have to save resources, and you have to build them up gradually. Do the best you can manage at this time. I don't propose to get back to [where I was] when I was 18. I would if I could but unlikely…*

In summary, age-related limitations hampered *self-efficacy* to be physically active for eleven participants. For some this lack of self-efficacy manifested in complete avoidance of physical activities. For others, it resulted in adjustment of the mode or type of physical activity. pacing strategies *(Behavioural Regulation)*. It was counteracted by a *Goal* to carry on despite this age-related lack of self-efficacy. The underlying individual differences in beliefs about age and its impact on physical activity are described in section: Appendix Q.

6.6.4.5.3 Self-efficacy related to HF symptoms

Five participants provided quotes in support of the following belief statement:

'Symptoms of my HF limit my ability to engage in physical activity' (n=5; k=17).

This belief was also present in those with mild decline in physical capacity (NYHA I-II). Thus, physical capacity does not always enable the behaviour. Perceived experience of symptoms does define physical activity. Breathlessness was the most salient symptom experienced by the participants that reduced capability to keep physically active and reduced confidence in being physically active. To illustrate:

> *Participant 14 (77 years old, male): I can't do a lot of it. I just don't have the breath left, unfortunately.*

Breathlessness, for Participant 9 resulted in avoidance of walking:

> *Participant 9: but I can't [walk], shortness of breath, very week, I am feeling. If it was not for breathlessness, I would walk more than I do. I used to walk more than I do now. Since I got this extreme breathlessness I can't. In fact, how far I can walk controls everything I do and where I go.*

On the other hand, people with a positive outlook, although lacking the capability to engage in physical activity, developed strategies to regulate their activity and were more self-efficacious despite 'lacking the breath' to engage in activities (Participant 7, 71, female):

> *All right. I don't get any breathless at night. I can't do at times during the day. If I if I hurry too much. So, I've learned how to pace myself.'*

It is important to note that shortness of breath prevents participants from pursuing health benefits that can be brought about by physical activity. Participant 9 (male, 74 years old) for example shared that he cannot walk due to the experienced breathlessness: '*I know there are some advantages [to physical activity]….but I can't, the shortness of breath*'.

Overall, low physical activity self-efficacy was present in all participants, however, some participants avoided physical activity of any form. While others accommodated a low intensity 'paced' activity, where possible. These individual differences are described in section: Appendix Q.

6.6.4.5.4 Self-efficacy related to the condition of the heart

A total of five participants (n=5; k =8) described their heart condition and reported that it limited their physical activity to varying degrees. Participant 9 for example shared:

> *Participant 9: Before then my heart was very poor. I had to stop every 2 steps. At the hospital they said, we can't do anything about it…but one side of your heart is not walking properly. Then I lost this weight, my heart is better, but I am very weak…and my blood pressure is very low. Doctor said that I have to change tablets for my blood pressure, so now I take 33 tablets a day.*

Overall, self-efficacy was affected by perceived impact of comorbidities, age, HF symptoms, and the perception and sense-making of one's heart condition. These beliefs and perceptions acted as a barrier to engagement in physical activity. For this was counteracted by *Behavioural Regulation* strategies like pacing which will be discussed below.

6.6.4.6 Behavioural Regulation

The following belief statements were identified:

'I monitor the intensity and/or duration of physical activity to make sure I do not overdo it' (n=2; k=6)
'I monitor intensity and or duration of physical activity to make sure I do enough' (n=3; k=4)
'I know when and where I will engage in physical activity over the next week' (n =3; k =4)
'I have a physical activity routine I follow' (n=3; k =9)
'I pace my physical activity to match my physical ability'
'When the weather is bad, I engage in physical activity indoors' (n=3; k=4)

Behavioural Regulation influenced physical activity in14 participants (n=14). They described its influence on their levels of physical activity in 57 quotes (k = 57). These quotes could reflect three types of behavioural regulation processes:

monitoring;
planning;
habit;
implementation intention.

Two participants monitored the intensity and duration of physical activity to a) either not '*overdo it' (Goal)*, when lacking physical ability (*Beliefs about Capabilities*);

b) to attain a behavioural goal (*Goal*). A lot of planning went into ensuring pacing the activities in accord with perceived ability *(Beliefs about Capabilities*). Implementation intentions in the face of barriers were in place in order to meet a behavioural goal (*Goal*). Implementation intentions are strategies to execute a goal-directed behaviour (Gollwitzer & Brandstätter, 1997; Gollwitzer & Sheeran, 2006).

6.6.4.6.1 Beliefs about Capabilities and monitoring

Two participants monitored their physical activity to avoid high-intensity physical activity due to their perceived lack of physical ability. For example, Participant 2 (76 years old, male) shared:

> *'When I go to the gym, a lot of machines have this heart monitor thing. And sometimes when something goes off the sky…ooouh [hesitation sound and gesture to indicate uncertainty and concern], 'Shall I be doing that?' So, I just slow down a little bit and start again. I try to keep my heart rate under 130.'*

Similarly, Participant 3 (80 years old, male): attempted to limit the amount they walk and aimed to not do more that they have been recommended:

> *'But I don't look at it (pedometer) until I feel I have done enough. 'Let's have a look at this.. oh well, it is over half an hour'...and then I stop. It is never more than 22'.*

6.6.4.6.2 Goal attainment and monitoring

On the other hand, others monitored the amount of physical activity to ensure they have reached their behavioural goal. Participant 5 (76 years old, male) for example shared:

> *If there are other arrangements. I then try to do it another time. I keep a schedule...I write down how much I am ought to do this week, and then I tick it off...and when I see I have not done it today, I try to do it another time*

Some participants used wearable devices to monitor daily activity. For example, Participant 8 used Fitbit to monitor their daily activity:

> *Yeah, I have my Fitbit, you can see how many steps I do. […] Fitbit encourages me to do more. […] Because I have this information. […] OK, 145 minutes… […] This is last week...Altogether, 30013 steps, look! It is in green and you know how much...you see. […]*

I think this one [refers to Fitbit] encourages me ...by going: 'yay, carry on carry on!!!' [Clapping].

Participant 8 also clarified later in the interview when asked if he engaged in physical activity before acquiring the Fitbit:

And before you got Fitbit did you do as much as you do now? Participant8: No...I did less...I still was doing it, but less. Especially I didn't have the record to see the results.

Monitoring the attainment of the behavioural goal (Goal) was a useful strategy to drive motivation and reinforce physical activity further. It is important to note that Participant 8 also holds positive beliefs about their capability (self-efficacy). Monitoring, thus, was an enabler in participants who perceived themselves as self-efficacious.

6.6.4.6.3 Beliefs about Capabilities and planning

Participants planned their engagement in physical activity. For example, Participant 7 shared:

Participant 7: Most days I walk a lot, everywhere. And when the schools come back I will start swimming again once or twice a week [...]

Participant 5 was mostly sedentary and very unwell. To be able to preserve his functioning, as advised by his health professional he engaged in an exercise according his schedule:

Participant 5: Or there are other arrangements. I then try to do it another time. I keep a schedule...I write down how much I am ought to do this week, and then I tick it off...and when I see I have not done it today, I try to do it another time

6.6.4.6.4 Habit

Another strategy used by some participants (Participant 2, 8, 15) included planning their engagement in physical activity when faced with barriers, like forgetfulness (Memory, Attention, and Decision-making Processes).

Participant 11, for example engaged in an exercise routine automatically (83, male):

I just wake up put my dressing gown on, go down the stairs, take my medication and do my exercises. It is just a routine. [...]But as a normal routine I just get up in the morning and do my exercises automatically.

Participant 7 (71, female), similarly, had a routine in place that she performed as everyday as part of a habit:

Participant 7 'when I wake up I do a series of exercises, my own exercises that last about 10 minutes. Those are the ones I do upstairs and then go downstairs put the kettle on. Then. I do my arm exercises, and I have got two lots of that, and then have a cup of tea in bed and then I get up. [...]

So, so with these exercises you've taken me through. You do this as a routine? Participant7: It's a routine. I do it every single day, every day

Participant 7 It's [morning exercise] a routine. I do it every single day, every day.[...]Like when I wake up in the morning I think: 'right, get up and spend a penny...erm...the, do My first lot of exercise upstairs which are mainly my legs and things. And then go downstairs and put the kettle on they do. The first lot of arm exercises make my pot of tea and then do the second lot of exercises. It's.. it's like... you know like...I take a cup of tea upstairs and then I get up and then I have a shower..I just do it. It is a habit.'

6.6.4.6.5 Implementation intentions

Implementation intentions are strategies that are executed to regulate a goal-directed behaviour, such as if-then rules that help in attaining a goal (Gollwitzer & Brandstätter, 1997; Gollwitzer & Sheeran, 2006). Implementation intentions shared by the participants were in place to regulate safe engagement in physical activity. Ten participants (n=10) planned their schedule for the day and activities. They thought about how much they can walk on any given day; and before engaging in any activities, would consider whether there will be an opportunity to stop for a break before they walk for longer than they can physically. They had many strategies for ensuring that their activity was safe. These quotes were summarised into the following belief statements (n=10, k=30):

I pace my physical activity to match my physical ability (n=10; k = 30);

When weather is bad, I engage in physical activity indoors (n=3; k=4)

Participant 4 (80 years old, female), for example, described her behavioural regulation strategy as follows:

> *'I find it quicker and better to sit down and rest until it settles down, take my inhalers and then start again gently.'*

Similarly, Participant 7 (71, female) planned ahead and balanced activities with breaks:

> *'I... sometimes if I hurry too much or going up a hill, I will get a bit short of breath. But I always...I pace myself more at home, which means if I'm in the middle of, say, cleaning or hoovering the house. I may have to sit down a bit more.'*

Participant14, on the other hand, regulated their activities by planning ahead, in order to ensure they do not exceed their ability:

> *'The thing that goes through my mind most of all, is how far I got to walk, it control a lot of the things I do, even if I go to a restaurant I would have to park nearby because if it is too far to walk, I will be white grim by the time I get to the restaurant...'*

Thus, planning and strategizing to mitigate the shortcomings of physical capability is a pervasive experience shared by the participants. As can be seen from the quotes above, a fair amount of effort went into pacing their activities throughout the day in accordance with their perceived ability.

Overall, participants engaged in *Behavioural Regulation* strategies, like monitoring and planning, having two behavioural goals (Goal) in mind: a capability corresponding goal, and goal attainment. They also had strategies in place (e.g. pacing) to attain a goal in the face of barriers (i.e. lack of self-efficacy, weather) suggest the relevance of the implementation intentions to physical activity in HF.

6.6.4.7 Optimism

Optimism domain was reflected in quotes from 10 participants:

'I am an optimistic person by nature' (n=6; k=8)
'I am optimistic about my ability to engage in physical activity (n=2; k=2)'

‘I am optimistic that engaging in physical activity will have positive outcomes for me’ (n=5’ k=13)
‘I am optimistic that I will engage in physical activity in the near future’ (n=n=4; k=5)

The following constructs were chosen to reflect the belief statements and corresponding quotes, respectively:

1) dispositional optimism;
2) Hope (hopeful about physical ability); or self-esteem
3) Hope (Hopeful about outcomes of physical activity, expectancy outcome model);
4) Situational optimism – the expectations that more positive outcomes than negative will happen in particular situations.

The relevant domains described so far were perceived either as a barrier or an enabler. This was also influenced by whether a participant perceived themselves as an optimistic person or not (Table 6.3). The following participants considered themselves as ‘an optimistic person by nature’: Participant 2, Participant 7 (71, female), Participant 8, Participant 11, Participant 14, Participant 16.

Table 6.3. The differences in the number of quotes across the relevant TDF domains between those who self-identified as optimistic and those who did not identify as optimistic grouped by whether the quote suggested that the domain is a barrier or an enabler

Domain	***Did not self-identify as 'optimistic', number of quotes***	***Did not self-identify as 'optimistic', average number of quotes per person***	***Self-identified as 'optimistic', number of quotes***	***I Self-identified as 'optimistic', average number of quotes per person***
Behavioural Regulation	**28**	**2.8**	**21**	**3.50**
Barrier	21	2.1	4	0.67
Enabler	7	0.7	17	2.83
Beliefs about Capabilities	*38*	*3.8*	*20*	*3.33*
Barrier	37	3.7	15	2.50
Enabler	1	0.1	5	0.83
Beliefs About Consequences	**54**	**5.4**	**28**	**4.67**
Barrier	35	3.5	10	1.67
Enabler	19	1.9	18	3.00
Environmental Context and Resources	**59**	**5.9**	**23**	**3.83**
Barrier	37	3.7	6	1.00
Enabler	22	2.2	17	2.83
Goal	**38**	**3.8**	**31**	**5.17**
Barrier	25	2.5	9	1.50
Enabler	13	1.3	22	3.67
Social Influences	**39**	**3.9**	**12**	**2**
Barrier	12	1.2	1	0.17
Enabler	27	2.7	11	1.83

Participant 8, for example, when asked about what encourages him to exercise responded:

> *Interviewer: 'And what does encourage you to do these exercises?*
> *Participant8: I am a positive man [...] I am a positive man!'*

Participant 14 also when describing his struggle with breathlessness, expressed:

> *'But I am an optimist by nature...and that that helps to keep going as well.'*

Participant 7 (71, female) defined herself as a positive person and formulated that in comparison with all humans who get older, adding that it is a matter for each individual to focus on wellbeing and that what she believes:

> *Participant 7 (71, female): 'We all get old, but If you can keep up I think...activity, seeing people joining things, being involved with people. I think that's, that's a very positive thing to do. And a lot of it is up to an individual. But this is what I believe. Yes.'*

Participant 11 expressed his positive attitude as follows:

> *Participant 11: The last thing to be to sit in a chair and tell yourself you are ill. You got carry on living. Seize the day.*

Another belief statement that reflect the *Optimism* domain is: 'I am optimistic about my ability to engage in physical activity', The exemplar quotes are reported below:

> *Participant1: 'ok, I can do that' ...and to say: 'I am going to walk all the way around. I can do that, I can hang from here'...and you gradually, well in my case, within a couple of weeks, I suppose... 'actually, I am now determined to go all the way around now.'*

> *Participant 10: Do you plan to do anything differently in future? Participant10: I would like to improve, but I do not suppose there is much hope for that.*

> *Yes! And how confident are you in being physically active? Participant8: Very confident! I am a positive man! You know I don't judge straight away....and when I judge I have to be careful to be fair...I don't know...wait, what was your question? Interviewer: So how confident are you in walking from 1 to 10? Participant8: Yes, I am 10.*

Participants who self-identified as an optimistic person by nature (n = 6), expressed negative outcome expectancies (*Beliefs about Consequences*) less frequently (k = 9) than those who did not (n = 10, k =26). Only two participants (Participant 8 and participant 14) talked about negative outcome expectancies. Participant 8 talked about a negative outcome – breathlessness – only in the context of regulating his physical activity to prevent this symptom:

> *Participant 8: And what happens when you try to run what stops you? Participant8: Oh, breathing! Then I shouldn't do it then...*
>
> *Participant 14: I am out of breath a lot of the time. If I go down the studio... it is in the vast distance, it is only about 100 feet. I just got off the freeway. But when I work, I stand when I paint...I don't like painting seated. When you paint you walk around an awful lot. So, I get out of breath, that's the trouble Interviewer: when you get out of breath do you feel you have to stop whatever you're doing Participant14: Yes.*
>
> *Participant 14: I am aware that I should keep a certain amount of activity going but it is makes me out of breath so much. I really don't do it, I can't do it. I mean I have a chair lift installed to go upstairs, because going upstairs is too much for me.And just the act of having to struggle to get out of the car made me very, very breathless.*
>
> *Participant 14: Well, I mean whatever I am doing and triggers off the breathlessness. I often have to completely stop whatever I am doing, just sit down for a couple of minutes or so...and then it slowly goes and then I can resume working again.... It can come on very suddenly. And I never know what is it that is going to trigger it off... whether it is getting out of the chair. Even shaving...if I wash my hair. Drying my hair...*
>
> *Participant 14: know exercise is good for me, but frankly it causes more...any kind of exhaustion causes problems, so I try to avoid it...*
>
> *Participant 14: I find I am just unable to. I find I get too out of breath and that makes me feel more ill than the lack of exercise.*
>
> *Participant 14: So, you tried to avoid it because it makes you feel...? Participant14: Well I try to avoid feeling more breathless than I need to...if I can avoid feeling breathless then I will , I don't enjoy it, it makes me feel ill, and I don't see any point in it...*
>
> *Participant 14: I am not exercising at the moment purely because it is making me out of breadth.*

Participant 15, when asked about what would happen if he increased his physical activity level, replied:

> *I can't do it. Because it will make me not do anything. And I will end up in the hospital.*

Similarly, participant 12 expressed a strong negative expectancy of physical activity:

> *any persistent walking or if I ought to go up and down the stairs several times. several times in succession I would become breathless and tired.*

On the contrary, the individuals who self-identified as optimistic, held more positive expectations. Participant 8, for example shared:

> *Interviewer: And what does encourage you to do these exercises? Participant8: I am a positive man, I like to be happy and I only found it if I do this I remain happy and you know it gives me...you know. Cheers me up, I don't have to have to be sad, jobless or workless or ill in front of my children. When I do this I can remain happy and smiley and things like that. Interviewer: Why did this changed since you got the heart problem? What was going through your head when you decided to...Participant8: I just carried on with life. Well, I get worried sometimes when I have pain. When the pain goes away I... you know... I'm back with my same feeling: 'positive man, happy man' and talking to the people.*

Similarly in regards to other domains, participants who did not self-identify as optimistic perceived more *Environmental Context and Resources* barriers than those who did. They shared a belief statement characteristic of perceived goal conflict and felt that they already engaged in enough physical activity (*Goal*). Contrary to other relevant domains participants who did not self-identify as optimistic relied on social support (*Social Influences*) from others to engage in physical activity. Overall, *Optimism* modulated how other relevant barriers and enablers influence physical activity.

6.6.5 Causal belief statements

The causal belief statements summarising the perceived links (i.e. cause-effect relationships) between domains that were shared by at least three participants are presented in Table 6.4. These were summarised into a causal graph Figure 6.2 .

Overall, breathlessness (*Dyspnoea*) limited perceived ability (*Beliefs about Capabilities*) among many participants and four (Participant 6, 8, 13, 14) expressed this in an explicit causal statement.

Environmental Context and Resources were causally linked to both *Goal* and *Behavioural Regulation* (Table 6.4). A health-related event was described by Participant 10 to cause the lack of physical activity goal priority. Whereas Participant 15 described curtailing his physical activity goal because of an implantable device. Two participants (Participant 10 and 16) described the causal role the major health-related event had in their habit breaking. A monitoring device (Fitbit) helped one participant to engage in physical activity and attain his goal.

The lexico-syntactic patterns suggest that *Social Influences* were explicitly causally linked to *Intention* and *Behavioural Regulation*. Three participants (Participant 2, 7, 15) who self-identified as active were inspired by a positive example set by individuals they viewed as role models. Participant 6 who did not self-identify as active, were affected by *Social Influences* in a different way. They intended to exercise (*Intention*) only when supported (practically and emotionally) by others (Table 6.4).

Beliefs about Capabilities was causally linked to *Beliefs about Consequences* and *Behavioural Regulation* (Table 6.4). Comorbid illnesses such as asthma (Participant 4) and atrial fibrillation (Participant 2) resulted in negative outcome expectancies associated with physical activity. Perceived lack of ability (*Beliefs about Capabilities*) also dictated the pace at which Participant 4 and 7 performed physical activities (*Behavioural Regulation*).

Negative *Beliefs about Consequences* negatively influenced behavioural goal (*Goal*). Participant 8, on the other hand, formulated a positive outcome goal as the result of positive outcome expectancies. These are described in detail in Table 6.4.

A negative *Goal* to avoid overdoing physical activity resulted in monitoring and action planning (*Behavioural Regulation*) aimed at reducing physical activity (Participant 2 and 3). *Behavioural Regulation* was driven by a positive *Goal* (outcome goal): to remain functionally independent in one Participant (Participant 1).

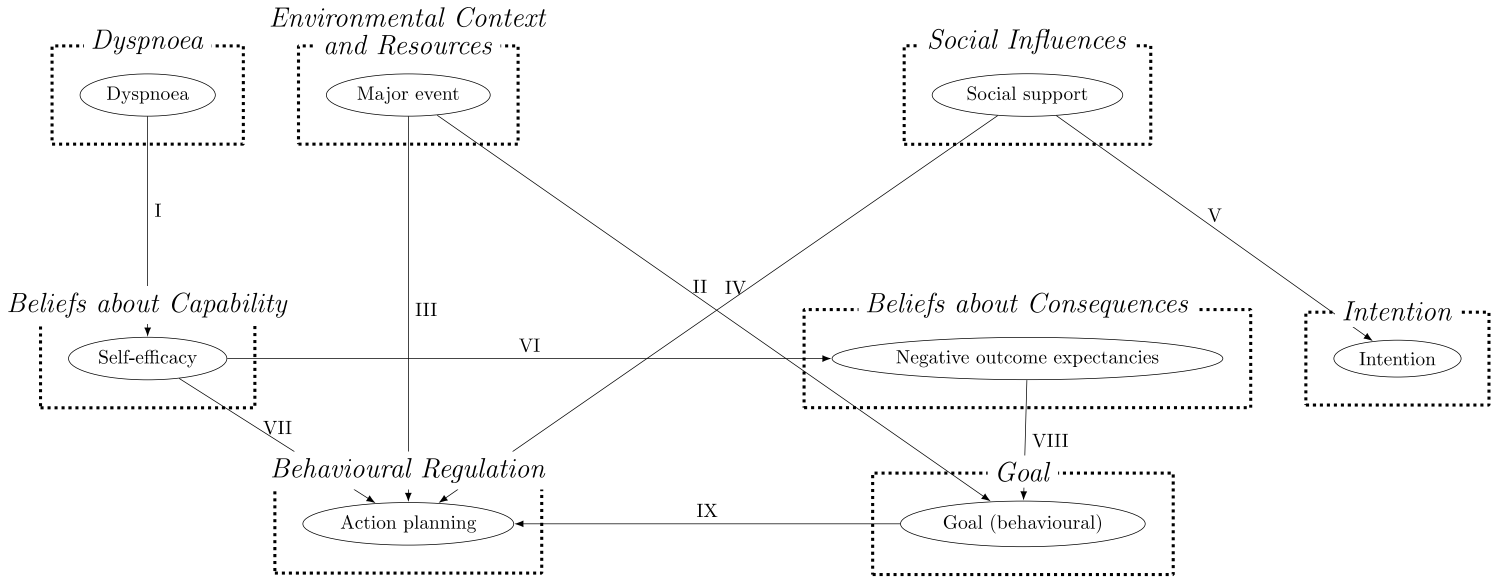

Figure 6.2. The graph summarising causal links as supported by the lexico-syntactic patterns analysis.

Table 6.4. The causal links described by at least three participants expressed in a belief statement.

The causal link and a belief statement	Participants	Illustrative quotes
I. Dyspnoea □ Beliefs about Capabilities I cannot engage in physical activity because I get out of breath. I should not engage in physical activity if I experience dyspnoea (severe breathlessness). Since I started experiencing breathlessness, I feel less able to walk.	Participant 6, 8, 13, 14	Participant 6: ‘Because I get breathless very quick and...We said about my blood pressure...there are lots of things, few things that I can’t do now, some are related to age and some are related to blood pressure.’ Participant 8: ‘Oh, breathing! Then I shouldn’t do it then. […] I feel tightness (points at chest), and I feel that I'm not fit for running, so I shouldn’t run, then I go fast walking and I found it difficult as well. So, no running; no fast walking…just normal walking’ Participant 14: ‘No, it is breathlessness. If it was not for breathlessness, I would walk more than I do. I used to walk more than I do now. Since I got this extreme breathlessness I can’t.’
II. Environmental Context and Resources □ Goal Group exercise programmes helped me to set suitable physical activity goals for myself.	Participant 1, 10, 15	Participant 1: ‘…and in those days, they probably still do, you had you know rehab… and it involves doing exercise… in a gym…erm For half an hour or so, you know… structured exercise… and it was there [when] I first learnt: ‘do as much as you feel comfortable with.’
III. Environmental Context and Resources □ Behavioural Regulation Monitoring devices (e.g. Fitbit) help me to monitor and regulate how much I engage in physical activity. A major health-related event resulted in physical activity habit-breaking	Participant 8, 10, 16	Participant 8: ‘Interviewer: And before you got Fitbit did you do as much as you do now? Participant8: No…I did less…I still was doing it, but less. Especially I didn’t have the record to see the results.’ Participant 10: ‘I don’t remember what it was, pacemaker probably. I don’t remember. I remember being told to be careful [after a surgery] for a few months and not to do exercises as such. Once you get out of the habit, you …it is hard to start again…it is difficult to start again, because you forget.’

		Participant 16: 'I tried to keep it going, because you must have some sort of discipline to keep it going, otherwise you just stop. I don't have a plan but I try to make sure that I don't miss too many'
IV. Social Influences Behavioural Regulation Making plans with others encourage me to engage in physical activity. I rely on others to plan and engage in physical activity.	Participant 2, 4, 5, 6	Participant 2: 'Yes, I do…I think…when I have decided to go out or scheduled to go somewhere…it normally takes me, as I said up to 10:30 to get ready but if somebody says I am going to pick you up at nine. I actually can be ready by nine.' Participant 4: 'Does planning your activities help you do more? Participant4: It would probably help me to do more, we certainly used to plan more, because we did it in conjunction with friends...and you have to plan if you are organising, but otherwise...' Participant 5: 'My wife helps me to keep up with the schedule. Interviewer: Amazing! What does your wife say about these exercises or your activity in general? Participant5: she is the driving force of me doing all these, really. (laughs) She makes sure I do the exercise and the rest of it…' Participant 6: 'As I am on my own, I would not make a plan...but if I was with other people, a friend and they exercised regularly, every Tuesday morning, and they asked me to join them'
V. Social Influences Intention I intend to engage in physical activity only if I am with others I intent to engage in physical activity being guided by the example of the people who are role models in my life.	Participant 2, 6, 7, 15	Participant 2: 'Yeah it is really, I copy after them (smiles)…Erm…I try to control my weight a bit…but…I have lost some recently. I should I should…again it is in the head, I got machines at home I could exercise on….but when I am by myself, I don't really have the motivation to do it.' Participant 6: '…if I had people, who were...going around on...erm...on...just walking really...or maybe the treadmill, you know people I know who are doing these things? I would, as a friend, I would join them, but I am not very good at going somewhere and getting on a treadmill and doing that for 10 or 15 minutes or whatever...and getting off and coming back home.'

		Participant 7: '[…]And I've always been active. My parents have always.. especially my mother, stressed the importance of being active, and to get out and do walking and everything. Yes. And I did it with my daughter… and my oldest, she does it with her daughter.' Participant 15: 'Older friends. They are marvellous in so many ways, and they had to get on with life. When I got to their age....I learnt from them: you got to do your best.'
VI. Beliefs about Capabilities □ Beliefs about Consequences I am aware of negative outcomes of physical activity (i.e. hospitalisation) that are part of having a comorbid condition.	Participant 2, 3, 4	Participant 2: 'I have my Heart…heart problem, I have atrial fibrillation […] And Erm…when I go to the gym, a lot of machines have this heart monitor thing. And sometimes when something goes off the sky…ooouh [tone of uncertainty], Shall I be doing that?' Participant 3: 'If I did more when I was quite asthmatic, by which I mean difficult to breathe, it would make it worse.'
VII. Beliefs about Capabilities □ Behavioural regulation I pace my physical activities accordingly to how capable and fit I fill at any given movement.	Participant 4, 6, 7	Participant 4: 'I find it quicker and better to sit down and rest until it settles down [breathing], take my inhalers and then start again gently. I am guided by my body rather than to force my body to do things.' Participant 7: 'I can do (get out of breath) at times during the day. If. I if I hurry too much. So, I've learned how to pace myself.'
VIII. Beliefs about Consequences □ Goal I reduce the intensity and amount of physical activity I aim to engage in order to avoid negative outcomes, such as hospitalisation and worsening of my condition.	Participant 2 ,3, 8	Participant 3: 'Because, you know… today I have done a bit of walking, and that's enough, you cannot overdo it. You tell your doctor that… they tell you off… they get upset if I don't do 22 minutes per day, and they get upset if you say I walked 45 minutes, Because they think some things might happen.'

		Participant 2: 'And sometimes when something goes off the sky…ooouh [tone of uncertainty]. I [then] just slow down a little bit and start again…I try to keep my heart rate under 130.' Participant 8: '[…] I found … If I do this [walking and meeting goals on Fitbit], [then] I remain happy; and, you know, it gives me…you know, cheers me up, I don't have to..don't have to be sad, jobless or workless or (f+) ill in front of my children. When I do this I [then] can remain happy and smiley and things like that.'
IX. Goal Behavioural Regulation I monitor my physical activity to make sure I do not overdo it. The goal to remain functionally independent pushes me to make plans for being physically active despite setbacks.	Participant 1, 2, 3	Participant 3: 'I bought this wristwatch; it is like a watch but it tells you how many steps you have done. Interviewer: Ah right! Does that help you to do more? Participant3: Well, no, it helps me to stop, cause if I have overdone 22 minutes. But I don't look at it until I feel I have done enough. 'Let's have a look at this.. oh well, it is over half an hour'...and then I stop. It is never more than 22.' Participant 2: 'No, because I know I got to do it to stay where I am. I know it is going to give me a problem … I could use the station's lift…but It is important that I don't… but, you know, with what I got, and the atrial fibrillation as well, I mean, it could have been acceptable for me to sit in a chair in a nursing home, basically… OK? But I dread the thought of that… so, I keep going.' Participant 1: 'Well, I was trying not to be, I was dependent on my wife carrying me up… and daughter…carrying me up to the gym to do the aqua-aerobics… (and of course part of the boredom factor, if you like…that's engendered.) That's why I bought the e-bike… I was… at least I could get around independently, without having to depend on my wife or daughter.'

Note 1: The quotes in green – the lexico-syntactic patterns supporting the causal links.

6.6.6 Summary of the results

The largest proportion of belief statements were coded as *Environmental Context and Resources*. The following domains were also judged to be relevant to physical activity based on the number of quotes: *Social Professional Role and Identity, Behavioural Regulation, Beliefs about Capabilities, Beliefs about Consequences*, *Emotion*, *Social Influences*, and *Goal*. Participants who self-identified as optimistic (*Optimism*) and those who did not differed considerably in the number of quotes identifying each domain either as a barrier or an enabler. Finally, *Breathlessness* reduced ability and damaged confidence (*Beliefs about Capabilities*). It led to persistent anticipation of negative outcomes of physical activity (*Beliefs about Consequences*). It caused negative somatic (i.e. uncomfortable sensation of being out of breath) and emotional experiences (i.e. anxiety; *Emotion*). Due to this multifaceted influence of breathlessness on physical activity, it is identified as a major barrier to physical activity in HF. The causal representation of barriers and enablers was also formulated in this chapter.

6.7 Discussion

The aim of this study was to identify and describe perceived barriers and enablers to physical activity in older adults living with HF. The following TDF domains were identified as relevant: *Environmental Context and Resources*, *Beliefs about Capabilities*, *Goal*, *Behavioural Regulation*, *Beliefs about Consequences*, and *Social Influences*. Considerable differences were observed in the perceived barriers and enablers between individuals who self-identified as active in comparison to those who self-identified as inactive persons and those who did not specify.

The theoretical domains that are suggested as key to physical activity in HF overlap with those identified to be relevant to the maintenance of behaviour change by a systematic review (Kwasnicka, Dombrowski, White, & Sniehotta, 2016). Kwasnicka and colleagues (2016) identified that *Social and Environmental Resources*, *maintaining motives* (congruence of the behaviour with self, enjoyment of the behaviour), *psychosocial resources* (e.g. depleted ego, reflective resource intensive processes or automatic processing of less effortful or near-effortless behaviours), habit, and *behavioural regulation* (monitoring and troubleshooting). The individuals included in this study acquired habitual physical activity behaviour long before the interviews took place. The last point at which the habit was disrupted was the major health event, taking place, on average, ten years before the interviews were conducted. Therefore, the behaviour and its influences described in this study are explained by the established nature of the behaviour.

Some similarities exist between the findings of this qualitative study and systematic review reported in Chapter 4. The following domains were identified as relevant in both: *Behavioural Regulation*, *Environmental Context and Resources*, *Beliefs about Capabilities*, *Beliefs about Consequences*, and *Social Influences*.

Social Professional Role and Identity domain was annotated from one study (Tierney et al., 2011a) identified in the review (Chapter 4). It was described as '*the change in the perception about oneself because of ageing'*. In this study ageing was descriptive of changes that influence perceived capability rather than a self-concept. Another domain that was identified in two studies (Tierney et al., 2011a; Pihl et al. 2011) was *Emotion*. The studies included in the review reported an unstructured account of influences. Therefore, most salient beliefs were likely to have been reported as been shown by previous research (Francis et al., 2009).

6.7.1 Perceived barriers and enablers to physical activity in HF

The specific beliefs summarising the barriers and enablers to physical activity are myriad (n = 78). In this section the constructs representative of these beliefs will be discussed in the context of available typologies, theories, and evidence. The lack of self-efficacy (*Beliefs about Capabilities*) influenced by the heart condition, comorbidities, and HF symptoms was a pervasive barrier to physical activity in HF. This finding is convergent with the findings of the meta-analysis of observational studies reported in this thesis. Previous qualitative evidence suggests that '*Changing Soma*' (Tierney et al., 2011) due to age, comorbidities and HF causes lack of perceived ability (i.e. 'negative beliefs about perceived ability' (Pihl et al., 2011). In this study, the extent to which self-efficacy determined the engagement in physical activity was defined by the degree of breathlessness as well as comorbidity. Self-efficacy also promoted resourcefulness in *Behavioural Regulation* (i.e. pacing oneself in accordance with perceived ability) as indicated by the causal belief statements.

The local environment, and exercise equipment and facilities (*Environmental Context and Resources*) were reported as both barriers and enablers. It was identified as an enabler if it has the following attributes: available at home, flexible settings (e.g. exertion levels to accommodate all levels of physical capacity), safe, and aesthetically pleasing in its appearance. An intervention typology (Hollands et al., 2017, 2013) describes these features as essential for a successful nudging of the behaviour as: functionality, availability and presentation, respectively. In HF, some tailoring to individual needs might be required (level of exertion being closely matched to their physical capacity and perceived ability).

The implantable device (*Environmental Context and Resources*) was a source of both – reassurance in, and worry about, physical activity. The NICE and European guidelines permit low to moderate levels of activities in this population. This category includes walking and daily activities, as well as low-impact aqua-aerobics activities. Only sports of bodily collision and highly vigorous competitive sports are not recommended to this population group. Therefore, rightly so, participants regulated the type of activities they engaged in. However, several misconceptions surrounding their implantable device were still present. This included battery usage and wires imposing risk on the heart. As suggested by the review of the perceptions about cardiac implantable devices, education on the safety of the device would be helpful to individuals living with HF who were fitted with an implantable device.

Major health-related events, such as cardiac surgery, cancer surgery, heart attack, the first HF decompensation and subsequent hospitalisation had a negative impact on physical activity for most of the participants (n = 7). These events were suggested to cause habit breaking as indicated by the causal lexico-syntactic patterns' analysis. The habit breaking follows a short period of clinically recommended rest (approx. three months). To put it in the words of Participant 10: “I remember being told to be careful. Once you get out of the habit [post-surgery], it is hard to start again…it is difficult to start again, because you forget.’. In addition, such events in HF are associated with drastic reduction in physical capacity.

A strong self-concept of an active person played a protective role for physical activity maintenance. The initiation of a physically active lifestyle was determined by the availability of an exercise programme shortly after the health event. This was supported by the lexico-syntactic patterns analysis. In addition, a significant life event – a crisis – is theorised to cause a shift in an individual’s identity (process of reinvention theory – Epiphaniou & Ogden, 2010; Ogden & Hills, 2008). The salience of the event may result in a radical shift in beliefs (Epiphaniou & Ogden, 2010). This is especially likely given the associated risks of sedentary behaviour in HF, including reliving the crisis all over again.

A number of constructs from the *Behavioural Regulation* domain determined physical activity in HF. These included implementation intentions – strategies to execute a goal-directed behaviour in the face of barriers (Gollwitzer and Sheeran 2006; Gollwitzer and Brandstätter 1997) such as bad weather, forgetfulness (i.e. routine), fluctuation of perceived ability (i.e. pacing of physical activities during the fluctuation of the perceived ability/ symptoms). The following strategies that require focus and effort were also useful: action planning; and self-monitoring. These are consistent with: Self-regulation theory (Kanfer & Gaelick, 1991) Relapse prevention theory (Marlatt & George, 1984), and Dual process model of self-control (Hofmann et al., 2008). *Behavioural Regulation* implies prolonged effortful control of behaviour and restriction, which may result in ego depletion – the loss of motivation, cognitive resources, and the focus on the behaviour (Kwasinska et al., 2016). Thus, making it an inconsistent enabler of the behaviour. Social and environmental resources such as social support and companionship (*Social Influences*) and monitoring devices (*Environmental Context and Resources*) were utilised to support *Behavioural Regulation* as indicated by the lexico-syntactic patterns’ analysis. *Beliefs about Capabilities* were causally linked to *Behavioural Regulation* constructs such as implementation intentions. The latter is consistent with the HAPA approach since it postulates that self-efficacy enables an individual to be resourceful in action planning and coping.

Clinical advice (enabler) and reassurance, Companionship, Social support (practical), Social support (emotional, barrier), Social support (emotional, enabler), Social comparison, Social support (practical), and Social modelling were all suggested to influence physical activity in HF. These Social Influences were explicitly causally linked to Intention and *Behavioural Regulation* as evident by the lexico-syntactic patterns. Three participants who self-identified as active were inspired by the positive example set by individuals they viewed as role models. Participants who did not self-identify as active intended to exercise only when provided with social support (practical and emotional) by others.

Negative *Beliefs about Consequences*, such as negative outcome expectancies (i.e. symptom onset and hospitalisation) were causally linked to the reduction in behavioural goal (*Goal*). Action planning was motivated by the positive outcome goal (*Goal)*: to remain functionally independent. A negative goal targeted at avoiding overdoing physical activity, resulted in monitoring physical activity with an aim to reduce physical activity (please see section: 3.6.4).

6.7.2 Breathlessness

Breathlessness is an overarching theme spanning two TDF domains: *Beliefs about Capabilities* and *Beliefs about Consequences*. Breathlessness also has a somatic and an emotional facet. In cardiac disease, when cardiac output and oxygenation is suboptimal (Chapter 1), breathing is increased to provide appropriate oxygenation (Weber et al. 1982). Due to this, the physical capacity to engage in physical activity is reduced and it places a burden on the cardiopulmonary system. This results in **Dyspnoea** – a clinical symptom of shortness of breath (Chapter 1). Breathlessness in HF is a threatening and aversive experience. Beside imposing physical restrictions in HF, breathlessness also directly punishes physical activity behaviour (*Reinforcement*: punishment). On the other hand, breathlessness is a fear-inducing somatic experience of HF and can be considered within the fear-avoidance model (Vlaeyen, Crombez, & Linton, 2016) and Common Sense Model, CSM (Leventhal et al., 1980). In this context, illness perceptions and perceived threat associated with breathlessness influence coping with HF and subsequently engagement in physical activity. Therefore, three interpretations of the impact of breathlessness on physical activity in stable HF exist: (a) Pavlovian conditioning and (b) operant conditioning (Skinner, 1974), and (c) cognitive-behavioural response to symptoms. While the former two are concerned with habit breaking (i.e., model-free processes), the latter is concerned with the underlying cognitive and behavioural response to somatic experience (i.e., beliefs about symptoms, catastrophising and dyspnoea-related fear-avoidance beliefs).

6.7.2.1 Breathlessness: Pavlovian and operant conditioning

Breathlessness in HF, as with any aversive stimulus, may elicit freezing (Dayan, 2012). The neutral stimulus – the somatic state of getting out of breath upon physical exertion – is paired with Dyspnoea in HF. This process is known as Pavlovian conditioning. In acute HF, getting out of breath often co-occurs with an immediate and threatening tightness in the chest. In the worst-case scenario it may require hospitalisation.

Because breathlessness acquires negative valence after the association with heart attack, physical activity becomes punishing because it induces breathlessness (Skinner, 1974). Such conditioning can be extinguished through repeated performance of physical activity. During this performance, the somatic state of being out of breath is not followed by pain or hospitalisation, so the pairing is unlearned.

Anticipation of punishments has been suggested to lead to discounting of future rewards potentially leading to suboptimal model-based evaluation of distal rewards (Estes & Skinner, 1941; Killcross, Robbins, & Everitt, 1997; Dayan & Huys, 2008; Huys et al., 2012). The distal rewards and gains of functional independence are discounted when experiencing immediate aversive stimulus such as breathlessness In HF.

Not only punishment following physical activity needs to be lifted, getting out of breath upon physical exertion needs to be paired with a positive reward. This happens in habitual physical activity over time when physical activity becomes intrinsically rewarding (Ryan & Deci, 2000). However, for habitual physical activity to be established, an individual needs to practice and repeat the behaviour (Lally and Gardner 2013). Individuals with HF find the experience of getting out of breath aversive enough that they do not engage in the behaviour at all in the first place. When they do persist, over time their exercise capacity improves (defined in Chapter 1) and permits them to engage in physical activity without limitations (Conraads et al., 2012).

Given stable condition and pharmaceutical treatment control, a previously aversive stimulus (i.e. 'breathlessness') is no longer followed by the negative outcome. The stimulus needs to acquire a new meaning, where it is paired to a desired outcome. This would extinguish not only the cue-outcome pairing such as 'breathlessness leads to hospitalisation', but also will give rise to a belief like 'getting out of breath at physical exertion improves health in future'. This can be described as a learned new identity of the stimulus in the new state.

6.7.2.2 Breathlessness: cognitive and behavioural response to somatic experience

The Common Sense Model (CSM) explicates behavioural and cognitive processes involved in the individuals self-management of perceived health threats (Leventhal et al., 1980; Leventhal et al., 2016). It is a model used to predict treatment adherence and lifestyle changes in response to a health threat (Leventhal et al., 2016). Illness beliefs such as illness *identity*, *controllability* of the condition, perceived *consequences* and *cause* of the illness, and *timeline* have been previously documented in a variety of health conditions (Chilcot, Norton, Wellsted, & Farrington, 2012; Hagger, Koch, Chatzisarantis, & Orbell, 2017; Hagger & Orbell, 2005), including cardiac disease (Aalto, Heijmans, Weinman, & Aro, 2005; Cooper, Weinman, Hankins, Jackson, & Horne, 2007; French, Marteau, Senior, & Weinman, 2002; Santos et al., 2020) and also was found relevant in explaining parental illness (Bogosian, 2012; Bogosian, Moss-Morris, Bishop, & Hadwin, 2014). The model predicted treatment adherence in a HF sample (MacInnes, 2014). The CSM also predicted cardiac rehabilitation attendance (Cooper, Weinman, Hankins, Jackson, & Horne, 2007). It has not been previously explored whether the model is relevant to physical activity in HF. In the present study, while illness *identity* (i.e., perceptions of the symptoms associated with HF) was found to influence physical activity in HF, other the CSM components were not.

In the context of the CSM, once an individual has acquired HF, they form beliefs about their illness. This includes perceived onset, rates, and duration of their HF (i.e., *timeline*). For example, an individual can perceive their HF as cyclical (i..e., something that comes and goes), acute (i.e., sudden onset and termination of ill-health) or chronic (i.e., a long-term condition). The present study did not identify that this belief influenced whether an individual engaged in physical activity. The CSM also includes anticipated *consequences* of having HF that affect the physical state, functioning and social life. The present study identified that the perceived *consequences* of having a HF manifested in a lack of self-efficacy to engage in physical activity (i.e., belief statement: "*I lack confidence in engaging in physical activity because of my heart condition*"). Participants equally attributed their lack of self-efficacy to other comorbid conditions such as COPD, atrial fibrillation and arthritis. Thus, rather perceived confidence to engage in physical activity is a key force on the behaviour. Finally, the extent to which one can control the course of their condition was also not found to influence physical activity.

On the other hand, beliefs about symptoms that characterise the illness (i.e., *identity*) influence treatment and engagement in physical activity. Participants perceived breathlessness as the key symptom characterising their HF. Furthermore, they associated this symptom with adverse outcomes such as heart attack and hospitalisation. This identity belief resulted in the avoidance of behaviours that induce breathlessness (i.e., physical activity). It is well documented that in chronic conditions, including HF, symptom-related fear impacts and shapes illness-related behaviours (e.g., treatment adherence, following exercise recommendation) (Åhlund, Bäck, & Sernert, 2013; Hagger & Orbell, 2003; Janssens et al., 2011, 2018; Leupoldt et al., 2017; MacInnes, 2014; Nelson & Churilla, 2015; Riegel et al., 2018; Santos et al., 2020; Yohannes, Junkes-Cunha, Smith, & Vestbo, 2017) Similarly, in this study catastrophising about breathlessness, which was strongly linked to having HF and indicated worsening of the condition, resulted in reduced physical activity. This cognitive response induced fear and avoidance of physical activity and further deconditioning (loss of capacity to exercise). In its turn, the deconditioning perpetuated the vicious circle of fearful avoidance of physical activity. This is consistent with the fear-avoidance model (Liu, Ng, Kwong, & Ng, 2015; Vlaeyen et al., 2016). Furthermore, it has been previously documented in COPD that fear-avoidance beliefs about breathlessness (dyspnoea) resulted in greater anticipation of getting out of breath and a negative emotional response to this somatic experience (Janssens, 2016), which is also consistent with the fear-avoidance model, which predicts that individuals who engage in fearful avoidance are hypervigilant to their somatic experiences and sensations. Overall, the firm belief that breathlessness is a somatic cue of having a HF (illness identity belief) together with a maladaptive coping with the condition, catastrophising, hypervigilance to symptoms, and fearful avoidance have a negative influence on physical activity engagement, which was observed in this study.

Overall, this study found that breathlessness is a somatic and emotional experience as well as a cue to physical activity disengagement. The implications of this for future physical activity interventions are discussed below. In addition, the finding of the multifaceted role of breathlessness in physical activity is explored in the quantitative phase of this research (Chapter 7).

6.7.3 Strengths and limitations

The participants recruited for this study are representative of the general population in terms of their age, and clinical and demographic characteristics. However, they may have a better clinical outcome prognosis. As such, this sample was hospitalised three times fewer days (five days) a year than the general population (British National Audit, 2018).

Semi-structured interviews were conducted. First, the participants were asked about their everyday physical activity and whether it changed since they got diagnosed with HF. In addition, an interview schedule was used (Appendix O). The researcher implemented the schedule flexibly (i.e., following a conversation and using the schedule's prompts in a flexible order). This may have helped in achieving a semi-structured interview. However, prompts may have resulted in suggestive answers from the participants. For example, while the participants shared the most salient barriers and enablers when asked an open question, they might have provided a forced answer following the prompt. Thus, the extent to which the interviews were truly semi-structured is limited.

Advantages of the approach include systematicity in describing narrated causal links. The systematicity was facilitated by clearly defined criteria for inferring causality – lexico-syntactic patterns. However, this also resulted in omission of the links that are drawn implicitly without apparent lexico-syntactic patterns. Therefore, this may impose a limitation since non-perceived causal links are not outlined within the presented causal structure.

The assessment of the validity of the qualitative findings proposed by Creswell et. al (2003) was carried out (Appendix S). Reflexivity and reflection were ensured throughout the study. Reliability of the coding was ensured through the development of the coding scheme as well as the inter-rater reliability analysis. The ecological validity of the findings was ensured through the recruitment of a representative sample and rich and thick verbatim analysis. The consistency of the findings was ensured through discussions with a panel of experts.

6.7.4 Clinical implications

According to the findings of this study, clinical advice and reassurance that reduces negative expectancies surrounding physical activity (e.g., secondary heart attack) is the first necessary means to physical activity change in HF.

The findings of this study also recognise that, in order to improve physical activity engagement in HF, one should address the detrimental effect of breathlessness on the behaviour. It is essential to engage an individual in physical activity, gradually increasing the intensity and duration. It is hoped that once an individual has built the physical capacity to engage in physical activity, has repeatedly been engaging in physical activity, and experienced exercised induced breathlessness without negative outcomes, they are more likely to build a new associations with breathlessness However, for a habit to be established, it is recommended to also pair the action (i.e., physical activity) to a cue that is placed in the everyday environment (e.g., a step or a treadmill) (i.e., Rhodes, Rebar, Gardner 2018; Woods 2003).

Furthermore, an education programme differentiating HF-related dyspnoea from the expected exercise-induced breathlessness is needed (i.e., reassurance in the safety of physical activity even when it induces getting out of breath. In addition to this, it is vital to address the fearful avoidance of physical activity and cognitive response associated with breathlessness. The common approaches to this include: Cognitive Behavioural Therapy (CBT) and Acceptance and Commitment Therapy, ACT (Al-Hammouri, Rababah, & Aldalaykeh, 2020; Ivanova, Jensen, Cassoff, Gu, & Knäuper, 2015; Powers, Zum Vorde Sive Vording, & Emmelkamp, 2009). While CBT can address the maladaptive cognitions and beliefs about breathlessness and its link to negative emotional response (i.e., anxiety, fear), the elements practised by ACT, such as acceptance of current avoidant behaviour maladaptive coping with breathlessness. Both approaches can be used in formulating behavioural strategies in response to breathlessness and fostering reproaching. Overall, a cognitive behavioural intervention that addresses the fear-avoidance response to breathlessness is deemed vital in engaging people living with HF in physical activity.

In addition, based on this study, it is recommended to engage individuals living with HF in a gradual increase in physical activity intensity, foster their skill mastery and use verbal persuasion which may help in improving physical activity self-efficacy (i.e., Bandura 2002). Simultaneously, it is important to set specific, measurable, achievable, relevant, time-bound physical activity goals and explicit action plans, including implementation intentions (i.e., if it rains, I will walk around the house). This study in particular, found that goal setting and behavioural regulation benefits from instrumental and emotional social support. For example, it is recommended to set goals and make plans with others who have a similar level of physical capacity to engage in physical activity as those affected by HF. Therefore, people living with HF might benefit from a walking group, where participants support each other in making explicit goals and action plans as well as social contracts to act on them.

The findings indicate a clear need for a behaviour change intervention that addresses the following perceived barriers: maladaptive beliefs about the major health-related event that preceded HF (e.g., heart attack, acute decompensation) as well as maladaptive beliefs about implantable devices that lead to fearful avoidance of physical activity. It is recommended to explore these beliefs in a non-judgemental and open manner, ensuring patient-driven change.

While it is not recommended to commence the exercise programme until an individual has not fully recovered and HF is stable (Chapter 1), the findings of this study recognise the need for explicit clinical advice and reassurance in the safety of physical activity (three months after a major health-related event), educational programme, CBT and ART to take place as soon as possible after the major event.

6.8 Conclusion

The present semi-structured interview study elicited 78 belief statements about barriers and enablers to physical activity in older adults (>70) living with HF. These belief statements and their pervasiveness across transcripts (i.e. number of quotes) suggest that breathlessness (i.e. Dyspnoea), *Beliefs about Capabilities*, *Environmental Context and Resources*, *Goal*, *Behavioural Regulation*, *Beliefs about Consequences*, and *Social Influences* are most relevant to physical activity in HF. Participants who self-identified as optimistic (*Optimism*) perceived more enablers and fewer barriers than their counterparts. Belief statements provide the basis for the content development of a scale designed to assess physical activity barriers and enablers in HF. The identified TDF domains suggest key constructs and domains that need to be investigated in a quantitative study. Causal belief statements were formulated to describe the causal links among the relevant TDF domains as perceived by the participants.

These links alongside the meta-analyses results provide the basis for models that will be formalised and assessed in Chapter 7.

7 Barriers and Enablers to Physical Activity in HF: Modelling and Feasibility Study

7.1 Introduction

Careful consideration of what brings about positive change in a behaviour is key to promoting health behaviours (Michie et al. 2014; Bartholomew et al., 2016; Aruijo-Soares et al., 2018; Hankonen and Hardeman, 2020). Therefore, to better understand how to promote physical activity in HF, in this chapter, constructs and the mechanism via which they bring about positive change will be considered.

The perceived causal structure of barriers and enablers to physical activity in HF suggested by the qualitative study (Chapter 6) provided insight into the constructs and mechanisms of action of how physical activity in HF is enacted. From an array of candidate theories (described in (Hagger, Cameron, Hamilton, Hankonen, & Lintunen, 2020; Hale et al., 2020)), the Health Action Process Approach (HAPA; (Schwarzer, 2016) theory was identified to most closely describe the results of the qualitative study. However, semi-structured interviews unearthed several constructs that matter specifically to the HF population that are not captured by the generic models. These include breathlessness and major health events as well as the concerns associated with physical activity. The present chapter will describe these constructs, survey relevant literature, and develop an auxiliary model explaining and predicting physical activity in HF.

Qualitative study (Chapter 6) delineated beliefs about barriers and enablers to physical activity in HF. The corresponding constructs theoretical domains and the causal structure underlying their influence on the behaviour were also identified. The identified relevant domains as described in terms of Theoretical Domains Framework (TDF, Cane et al., 2012), were *Environmental Context and Resources*, *Beliefs about Consequences*, *Beliefs about*

Capabilities, *Intention*, *Goal*, *Behavioural Regulation*, and *Social Influences*. The additional key domain was breathlessness. The causal structure suggested by the causal belief statements summarised from the parses within transcripts can be described as follows. Experienced breathlessness reduced perceived ability to engage in physical activity (*Beliefs about Capabilities*). Perceived ability caused negative outcome expectancies associated with physical activity (*Beliefs about Consequences*), suggesting perceived susceptibility to undesired outcomes (risk perception associated with engaging in physical activity). Lack of self-efficacy and actual capacity to engage in physical activity safely also caused the need to resort to strategies such as pacing the intensity of physical activity when feeling unfit (i.e. slowing down, stopping) and not making use of action planning (i.e. scheduled activities; *Behavioural Regulation*). Recall and negative impact of a major health event (*Environmental Context and Resources*) resulted in a similar downregulating of physical activity by means of *goal setting* to reduce the intensity and the amount (*Goal*), which then caused elaborate action planning to avoid engaging in physical activity (*Behavioural Regulation*). Social support was a self-regulatory resource: making plans (*Behavioural Regulation*) to engage in physical activity with friends and family (*Social Influences*) enabled physical activity. Being with others (*Social Influences*) ensured safety and prompted physical activity engagement. Role modelling (from the example set by physically active parents in earlier life, and friends later) influenced *Intention* to engage in physical activity. Such a pattern alludes to HAPA theory (Schwarzer, 2016) as explained in Chapter 6, as well as to the context-specific constructs and the causal structure of their relationships. In this chapter, the qualitative findings will be formalised using computational modelling methods (Guest & Martin, 2020).

7.1.1 Health Action Process Approach

The Health Action Process Approach (HAPA) provides a close account of the barriers and enablers to physical activity according to the qualitative findings reported in Chapter 6. HAPA is a dual-phase social-cognitive model of behaviour (Schwarzer, 2008). The two phases are motivational phase and volitional phase. They are partitioned by the presence of *intention*. *Intention* is defined as a conscious decision to perform a behaviour or a resolve to act in a certain way (Cane et al., 2012). It is also defined as an extent to which individuals will invest effort in enacting a given health behaviour in the future (Schwarzer, 2008; Zhang 2019; Fishbein and Ajzen, 1975). The motivational phase specifies behavioural determinants and processes that predict the formation of *intention*. The volitional phase describes the determinants and processes responsible for the translation of *intention* into behaviour. Such distinction of the phases is consistent with the intention-behaviour gap (Sheeran & Orbell, 1999), which has frequently been observed in empirical studies (Sniehotta, Scholz, & Schwarzer, 2005). The intention-behaviour gap describes the discord of overt behaviour with previously verbally expressed *intention*. In other words, *intention* does not always predict behaviour. Recognition of the role of volitional processes in ensuring the enactment of behaviour is further supported by implementation-intentions strategies (Gollwitzer & Brandstätter, 1997; Gollwitzer & Sheeran, 2006); Please see the discussion in Chapter 6).

Distinct constructs are implicated at each phase according to HAPA. At the motivational phase, *outcome expectancy*, *risk perception*, and phase-specific *self-efficacy* predict *intention* formation. At volitional phase, *coping planning*, *action planning*, and phase-specific *self-efficacy* predict behaviour. *Self-efficacy* is also phase specific. *Action self-efficacy* – perceived ability to adapt behaviour – influences *intention* formation. While *maintenance self-efficacy* – perceived ability to maintain the behaviour – and *recovery self-efficacy* –perceived ability to recover during setbacks – influence the volitional strategies, such as *action* and *coping planning*, respectively (Schwarzer 2008).

It is not surprising that HAPA stood out as the most relevant theory given the hypothesized constructs and mechanism of action inferred from the qualitative study. That is because HAPA is an especially good account of the enactment of physical activity behaviour as suggested by numerous studies (Gholami, Knoll, & Schwarzer, 2014; Zhang, Zhang, Schwarzer, & Hagger, 2019). As such, a meta-analysis of 95 observational studies (Zhang et al., 2019) found that the effect of action *self-efficacy* on *intention* is behaviour-specific and may play a more prominent role in physical activity than other behaviours. One explanation for the repeatedly replicated relevance of HAPA to physical activity is that the focal behaviour is not affected by distracting impulses as much as other behaviours such as diet and smoking cessation. Instead, physical activity requires large motivational resources to form an *intention* to act, and then execute the goal-directed behaviour (Zhang et al., 2019).

Thus, because physical activity requires these large motivational and volitional resources it is explained well by HAPA.

There are, however, several distinct features that are unique to physical activity in HF. The findings of the presented qualitative study that diverged from HAPA are: (i) the role of breathlessness and its contingency with the experienced health events; (ii) the role of behavioural goal; iii) the importance of perceived concerns and risks associated with physical activity in HF. These findings are formally expressed as a set of hypothesises and form the basis for the auxiliary models to be tested in the present chapter.

7.1.2 The role of Breathlessness

As reported in Chapter 6, Breathlessness was a pervasive and persistent barrier. The influence of the perceived symptom of breathlessness on physical activity was multifaceted. On the one hand, breathlessness reduces perceived ability to engage in physical activity (*Beliefs about Capabilities*). On the other hand, breathlessness was perceived as a negative outcome of physical activity (*Beliefs about Consequences*), which often followed with an attempt to reduce the intensity of physical activity. Therefore, the level of breathlessness, alongside the domains its impacts, is an overarching factor.

Individuals with HF experience breathlessness (i.e. dyspnoea) during a health event – heart attack or acute cardiac decompensation. They then associate getting out of breath during exercise with the health event. The health event results in habit breaking. On the other hand, having a physical activity routine has a positive influence on physical activity in HF. The role of breathlessness, health event, and routine highlight the importance of habitual and Pavlovian processes underlying physical activity behaviour in HF.

As has been outlined by previous reviews, the main limitation of HAPA, and other social-cognitive models is the lack of an account of automatic (i.e. non-conscious, intuitive, model-free, non-goal directed) processes and determinants that are not based on explicit cognition and belief ((Rebar, Rhodes, & Gardner, 2019; Zhang, Chung, Zhang, & Schüz, 2019). Humans often engage in behaviour automatically (i.e. without explicit decision-making). The importance of automatic processes is reflected in findings indicating that past behaviour predicts future behaviour far beyond HAPA (Zhang et al, 2019) and many other social and cognitive models (Rhodes et al., 2018). HAPA therefore describes only the deliberate processes underlying behaviour. It omits the automatic processes. Specifically, in HF, this is especially important in understanding what influence physical activity because of the Pavlovian association between breathlessness and the health event, and its impact on physical activity.

Automatic and deliberate processes are described by dual processes frameworks (i.e. (Borland, 2017; Dayan, 2009; Shiffrin & Schneider, 1977; Tversky & Kahneman, 1974). With variable emphases, these frameworks distinguish not only automatic processes from deliberate, but also habitual from goal-directed, fast from slow, System 1 from System 2 (Tversky & Kahneman, 1974), data-bound (estimated from continuous repeated experience) from prior-bound (based on a cognitive representation; Huys 2007), procedural from declarative (Squire, 2004), and difficult to extinguish from hard to maintain behaviours (Borland, 2017). Collectively, these dichotomies will be referred to model-free (MF) vs model-based (MB) learning below (Dayan & Berridge, 2014; Dayan, Niv, Seymour, & Dawa, 2006).

MF learning involves accumulation of estimates of the long-run values of circumstances and actions from retrospective experience (Dayan & Berridge, 2014). MF learning is automatic, bears low cognitive demand and does not involve high order beliefs like those that were elicited in the qualitative study. MF Instrumental learning involves making a choice provisional on the expected outcome of the choice or past experiences with the choice. According to this theory (Dayan & Berridge, 2014), MF instrumental learning is key to the acquisition of new behaviours and the exertion of behavioural control.

In individuals with HF, MF instrumental learning may cause the avoidance of physical activity upon the experience of breathlessness. Consider an individual who engages in habitual physical activity. They are used to getting out of breath upon moderate to vigorous physical activity. When they experience a health event, they acquire a new association between breathlessness and the terrifying event. This newly learned negative association may cause them to lose the physical activity habit. The new habit is learnt fast and is resistant to change (Tversky and Kahneman, 1974). As the result, habitual physical *in*activity is established. Thus, breathlessness necessitates the description of MF/Pavlovian processes implicated in physical activity engagement in this clinical population.

MB learning on the other hand, uses cognitive representations of the environment, complex beliefs, beliefs about future outcomes, and subjective probability of their occurrence, to generate goal-directed behaviour (Daw, Niv, & Dayan, 2005 ; Dickinson & Balleine, 2002 ; Doya, 1999). These representations are used in making decisions. MB processes are cognitively demanding (Tversky and Kahneman, 1974).

MB processes in the context of physical activity in HF involve formation of coherent cognitive representation of the disease and consequences of physical activity. For example, an individual with HF learns, and over time incorporates into their cognitive representation, that physical activity improves cardiac health and facilitates the attainment of functional independence (Chapter 6). Such cognitive representation dictates the decision to act – engage in physical activity – given the anticipated desired outcomes and the estimated likelihood of attaining them (Tversky and Kahneman, 1974). The individual then engages in goal-directed behaviour (e.g. engagement of planned physical activity). This goal pursuit requires motivational resources (Schwarzer et al., 2008) and volitional strategies such as action and coping planning as described by HAPA.

The theory of MB-MF-Pavlovian reward learning (Dayan & Berridge, 2014) suggests that MB and MB processes interact and produce intermediate learning. Intermediate learning describes the process during which an individual enacts a behaviour being governed by beliefs, and cognitive representation of the self, illness, and environment (MB) and by MF learning resultant from the experience of physical activity in the context of HF and physiological states that come with it (i.e breathlessness, comorbidity, age). For example, the MB element involves a qualitative change in the way the stimulus is perceived upon gaining new factual knowledge (i.e. ‘getting out of breath is good for me because that is how I train my heart’) followed by extinction of the pairing between breathlessness and health events. A model that describes both MF/Pavlovian processes as well as MB processes (including those in HAPA) is expected to provide a better account of physical activity in HF.

7.1.3 The role of behavioural goal and *Behavioural Regulation*

As indicated by the qualitative study, behavioural goal defined as – mental representations of (behavioural) outcomes or end states that an individual wants to achieve (Davies et al., 2012) – is key to physical activity in HF. The auxiliary hypothesis therefore predicts that behavioural goal is a requisite for enactment of physical activity, and intention alone does not suffice (please see Chapter 6). Furthermore, in the most recent articulation of HAPA the authors (Schwarzer & Hamilton, 2020 in Hagger et al., 2020) highlighted two elements of intention: goal setting and goal pursuit (Hagger et al., 2020). Here, it will be outlined why a goal might predict behaviour to a greater extent than intention.

Behavioural goal is differentiated from intention by its specificity in terms of target behaviour. As such, a specified conscious decision to perform a behaviour (i.e. intention) is described at the level of specificity that corresponds to the behaviour (Ajzen and Fishstein, 1975). According to goal setting theory (Locke & Latham, 2006), setting a behavioural goal directs individuals’ attention, resources and effort toward obtaining proficiency (i.e. fluency and skill) and increased level (i.e. moderate physical activity) of the behaviour.

In HF, the intention to enact the behaviour can be supplemented with a detailed behavioural goal described in terms of the target behaviour (i.e to go for a stroll, or to engage in gardening). Indeed a meta-analysis of interventions designed to increase physical activity across diverse samples and settings found that setting a behavioural goal has a moderate effect on the levels of physical activity (McEwan et al., 2016). Further exploratory analysis revealed that when goal is formulated in terms of the target behaviour (i.e walking, aerobic exercise) rather than general physical activity it has larger positive effects on the behaviour

(McEwan et al., 2016). The specificity in terms of duration, time, and amount did not have implications for the behaviour enactment (McEwan et al., 2016). Especially when capacity, i.e. self-efficacy to achieve the specified duration, intensity of physical activity is low (McEwan et al., 2016). This is the case in HF too.

Goal pursuit (Abraham & Sheeran, 2003; Gollwitzer & Sheeran, 2006; Hagger et al., n.d.) also demands time and resources. When multiple goals are sought, time and resources are split across these goals. In daily life goal attainment competes for these limited resources (Kruglanski et al., 2018). Therefore, goal pursuit has the following attributes: goal priority (Conner et al., 2016); goal facilitation, and goal conflict (Riediger & Freund, 2004). Goal priority refers to the prioritisation of time and energy expenditure on one goal over other goals (Conner et al., 2016). Goal conflict describes the extent to which the pursuit of one goal inhibits the pursuit of another, and goal facilitation describes the extent to which the pursuit of one goal enhances the pursuit of another (Riediger & Freund, 2004).

Observational studies show, as compared with active individuals, inactive individuals have more goals that compete with their physical activity goal (Gebhardt & Maes, 1998). Inactive individuals value their conflicting goals more than their engagement in physical activity and are less self-efficacious in their simultaneous pursuit of both (Karoly et al., 2005). Inactive individuals also perceive physical activity goals as less facilitative of other valued goals (Jung & Brawley, 2010). In contrast to observational studies, prospective predictive studies do not support a significant relationship between goal conflict and physical activity levels (Li & Chan, 2008 ; Presseau, Sniehotta, Francis, & Gebhardt, 2010; Riediger & Freund, 2004).

Goal facilitation is a construct distinct from goal conflict (Presseau et al., 2010 ; Riediger & Freund, 2004). It is not merely the opposite end of a goal conflict spectrum. Prospective cohort studies have shown that goal facilitation predicts self-reported physical activity (Presseau et al., 2010). The studies on the extent to which each attribute of a goal – facilitation, conflict, and priority – was influencing physical activity offer conflicting findings. In a study (Presseau, Tait, Johnston, Francis, & Sniehotta, 2013) with a sample of

103 healthy adults, goal conflict and goal facilitation were assessed as predictors of moderate to vigorous physical activity (MVPA). Perceived goal facilitation predicted MVPA above intention and perceived behavioural control. While goal conflict impeded MVPA (Presseau, et al., 2013). The authors concluded that perceived goal facilitation is a significant predictor of MVPA over and above intention. However, the time spent pursuing conflicting goals attenuated this association (Presseau et al., 2013). Another experimental study suggests that goal conflict did not moderate the relationships between intention and physical activity (Conner et al., 2016). Instead, intentions were found to be a strong predictor of physical activity when goal priority is high (Conner et al., 2016). The findings of both prospective and experimental studies suggest that goal priority moderates the intention-behaviour relationships (Conner et al., 2016). According to the qualitative findings of the present work (Chapter 6), in HF, increasing physical activity is, on one hand, perceived as facilitative of the goal to achieve functional independence, and as conflicting with this goal, on the other hand. The conflict is due to the belief that physical activity exacerbates HF symptoms. Those holding the latter belief, did not prioritise physical activity.

As suggested by the qualitative study findings (Chapter 6), *Behavioural Regulation* was an important determinant. *Behavioural Regulation*, which can be defined as the regulation of self and the goal-directed behaviour in pursuit of desired outcomes (Bandura, 1986), also is a volitional process and helps to bridge the intention-behaviour gap (Sniehotta et al., 2015).

Behavioural regulation is a source for the enactment of physical activity among young adults (Rovniak, Anderson, Winett, & Stephens, 2002). However, this might not be the case for older adults as suggested by a meta-analysis (French & Olander, 2014). This study also found that in HF a lot of self-regulatory effort is spent on avoiding physical activity as a result of concerns associated with it.

The following manifestations of behavioural regulation exist: self-monitoring, correctives following reflective feedback on behaviour and the achieved outcomes (Bandura, 2002), coping planning, and action planning (Locke & Latham, 2006). All these types of behavioural regulation, in HF, are implemented in the pursuit of conflicting goals (outcomes): to increase physical activity and attain functional independence; and to avoid physical activity and subsequent ill-health (i.e. getting out of breath, secondary heart attack, acute decompensation).

Overall, it is expected that behavioural physical activity goal will have a positive impact on behaviour in HF, when it is: a) described in terms of target behaviour ('goal specificity'; i.e. to increase walking or aerobic exercise); b) without detailed description of specific intensity or duration; c) prioritised; d) facilitative of; and e) not in conflict with the goal of functional independence. Furthermore, goals with these attributes are predicted to improve behavioural regulation of physical activity. But when these attributes are not satisfied, it may result in efforts to downregulate physical activity. Therefore, concerns that conflict with physical activity goals in HF should be described in the model.

7.1.4 The role of risks and concerns associated with physical activity in HF

Risk perception, defined as a perceived health threat and the subjective judgement about one's susceptibility to it (Schwarzer & Hamilton, 2020 in (Hagger et al., n.d.)). The risk is framed as avoidable if precautionary measures like health behaviour are in place. Risk perception was not found to be a significant determinant of physical activity in studies evaluating the explanatory power of HAPA according to the recent meta-analysis (Zhang et al., 2019). Similarly, the risks imposed by HF that an individual might be susceptible to if they do not engage in physical activity were not identified relevant in Chapter 6. This supports the notion that individuals *cannot* be 'scared *into'* engaging in a health behaviour (Hagger & Hamilton, 2020). However, concerns and negative outcomes associated with increased engagement in physical activity in HF were relevant hindrances to the behaviour (Chapter 6). This suggests that HF individuals *can* be 'scared *out'* of physical activity.

One explanation for this finding comes from conceptualising physical activity as a treatment. Physical activity, in fact, is a treatment strategy and is routinely recommended to HF patients by health professionals (Chapter 1). The beliefs affecting physical activity, therefore, share some similarities with beliefs about treatment. In a similar manner to the causal structure outlined by the Necessity and Concern Framework (Rob Horne, 2020; Rob Horne et al., 2013), concerns about engaging in physical activity were identified as barriers to the adherence to physical activity as a treatment in Chapter 6. Breathlessness can be seen as an undesired 'side-effect' of physical activity. There are also concerns about potential outcomes of physical activity (i.e. decompensation). Some individuals perceived personal susceptibility to the negative outcomes, which exacerbated their risk perception. Thus, risk perception about physical activity engagement is a key barrier. However, it is qualitatively different to the risk perception explicated by HAPA and instead, is more similar to the Necessity and Concerns Framework construct 'concerns'.

7.1.5 Small *N* methods and Computational modelling methods

The achieved sample size for the study reported below was extremely small (*N*=3). HF patients are challenging to recruit. Additional recruitment difficulties were imposed by the COVID-19 outbreak. Individuals living with HF are a shielding population group, as both HF and age introduce a high risk of mortality in case of contracting COVID-19. Due to the small sample size being achieved as the result of recruitment difficulties, alternative methods suitable for testing hypotheses with small samples were adopted and will be reported below.

Strong assumptions are needed to assess and draw conclusions from small datasets (van de Shoot & Miocevic, 2020). These assumptions must be expressed in a computable format (West et al., Hale et al., 2020). Therefore, the assumptions described in this introduction were expressed in a model and computable format.

In addition, computational modelling was motivated by the following. The barriers and enablers to physical activity in HF and the relationships among them, as well as the theories that most likely represent these, are usually described using natural language. However, such description of models and theories in psychology has invoked criticism (West et al., 2019; Hale et al., 2020). The use of natural language introduces ambiguity (Oberauer and Lewandowsky, 2019), which may limit model comparison, testing and development. In order to ensure the testability of models, they should be precisely represented and disambiguated (Hale et al., 2020; Borsboom et al., 2020; Forstmann et al., 2011; Guest & Martin, 2020; Haslbeck et al., 2019; van Rooij & Baggio, 2020). Overall, the following criteria for rigorous model development are generally agreed upon (Popper, 1963; Rothman et al., 2008): plausibility, internal consistency, parsimony (i.e. stripped of arbitrary elements), explanatory power (i.e. capturing as much variance as possible), falsifiability (i.e. predictions detailed enough to be disconfirmed by empirical evidence).

Since physical activity is a complex behaviour, it is subject to a myriad of causes, many of which are unknown (O'Cathain, Croot, Duncan, et al., 2019). To design interventions, The Medical Research Council (2008) recommends first building an understanding of what needs to change and how that change should take place. One approach is to incorporate theoretical insights into an explicated model of complex behaviour (Hankonen & Hardeman, 2020). The qualitative research (Chapter 6) provided the insights into what should change. The present chapter, drawing on the existing theory and the qualitative findings, sets out to explicate the causal chain of how physical activity can be improved in HF.

Recently, many have issued calls to build models in psychology that are plausible, parsimonious, predictive, and falsifiable (Guest & Martin, 2020; van Rooij & Baggio, 2020; van Rooij & Blokpoel, 2020). This requires models to be formally (mathematically) specified and independent of details of implementation (Guest & Martin, 2020; Marr & Poggio, 1976; van Rooij & Baggio, 2020). This facilitates the development of models that can be assessed, disputed, and amended (West et al., 2019; Guest & Martin, 2020; Van Rooij et al., 2020; Hale et al. 2020). In response to this call, in this chapter, the cause-effect relationships underlying physical activity in HF are represented mathematically, diagrammatically, and computationally. The following steps are followed in model development: model description, model specification, model implementation, and hypothesis testing (Guest & Martin, 2020). It is hoped that such detailed formal description will assist future research on physical activity in HF.

7.2 Aim

The aim of this chapter is twofold: 1) to describe a formal model of barriers and enablers to physical activity in HF; and 2) to assess feasibility of a cross-sectional study assessing the model and to estimate a sample size required to empirically assess models.

7.3 Research question

- Is the model of barriers and enablers to physical activity elicited in Chapter 6 identifiable, plausible, and falsifiable?
- What is the sample size required to test predictions made by the model of barriers and enablers to physical activity in HF?

7.4 Objectives

The objectives are:

- To perform a power analysis to inform the feasibility of a large observational study.
- To assess whether the models are plausible and identifiable using computational modelling;
- To test hypotheses implied by the models using a small sample size:
    i. Hypothesis 1 (H1) is: Behavioural Goal will explain the variance in physical activity in HF to a greater extent than Intention
    ii. Hypothesis 2 (H2) is: Causal relationships predicted by HAPA will predict physical activity behaviour in HF better than a null model that does not incorporate those relationships (not H2)
    iii. Hypothesis 3 (H3) is: An auxiliary model – as described – will predict physical activity in HF to a greater extent than HAPA

- Hypothesis 4 (H4) is: The MB-MF-Pavlovian where the MB element is the Auxiliary model will explain physical activity variance in HF to a greater extent than the MB-MF-Pavlovian model where the MB element is HAPA.
- To improve the content validity of a HF-specific scale assessing Barriers and Enablers to Physical Activity in HF (BEPA-HF).

7.5 Methods

The qualitative results – the causal representation of the perceived barriers and enablers to physical activity (Chapter 6) – are described in a directed acyclic graph (Pearl, 2009), and a series of structural equations (Pearl, 2009). Models are then simulated and empirically assessed in a small cross-sectional study.

7.5.1 Model specification

Specification is a step taken to formally describe the qualitative assumptions consistent with a model in terms of mathematical functions, logical or structured expressions (Guest & Martin 2020; Rooij & Baggio, 2020). It is a challenge to formulate the structural and logical expressions of psychosocial models due to the inherent complexity of the subject matter— human behaviour. Three simplifications therefore are made.

First, the relationships between the variables are assumed to be hierarchical and acyclical. Second, the models describe a set of variables and mechanisms that can be understood under the framework of this study (please see Chapter 2). Third, stochasticity is introduced at the level of the variables that are exogenous to the model (i.e. are independent from the model's assumptions and are imposed on the model, such as age, number of comorbidities, and presence of an implantable device). Two methods are especially relevant to describing psychosocial models given these assumptions: structural equation modelling and structural causal modelling.

7.5.2 Structural equation models

A structural equation model is a set of linear equations which describe the relationships between latent variables of interest, $y_i = w x_1 + \ldots + w_n x_n + u$ (Pearl, 2009). A latent variable is a variable that cannot be directly observed and measured, and instead must be inferred from a set of indicator variables (i.e. scale items' scores). The first part of a SEM model includes a measurement model which describes the relationships between indicators and latent variables. The indicators included in this study are scale scores obtained for each underlying construct. The second part of SEM describes the relationships between endogenous latent variables (i.e. constructs). An endogenous variable is a variable whose value is determined by the model and its assumptions (Pearl, 2009). In this study, SEMs describing HAPA, Auxiliary, and MB-MF-Pavlovian models were specified as described in Section 7.6.2.1.

7.5.3 Structural causal models

Often health psychology theory describes causal structure underlying processes that gives rise to behaviour. This causal structure can be expressed as a set of conditional independence assumptions, written $Y \perp\!\!\!\perp X \mid C$. Read this as Y is conditionally independent of X given C. Such a set of assumptions can also be expressed as a directed acyclic graph (*DAG*).

A *DAG* is a set of nodes, representing variables, and directed edges connecting them, representing relationships (see Figure 1). A *DAG* represents a set of conditional independence assumptions by the edges it does not include. That is, the included edges indicate a dependence relationship. For example, the graph in Figure 1 denotes the conditional independence relationships: $Y \perp\!\!\!\perp X \mid C$, $Y \perp\!\!\!\perp A \mid C$, and $Y \perp\!\!\!\perp B \mid C$.

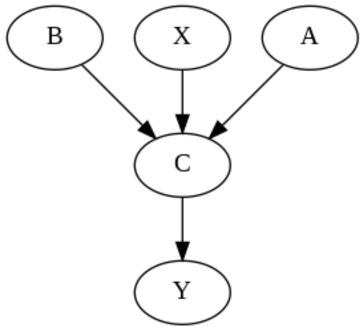

Figure 7.1. An exemplar model is a structural causal model with a set of exogenous (X, A, B) and endogenous variables (C), where Y || X, C.

Note: Two kinds of nodes exist: child and parent. Arrows point from parent nodes to child nodes. In this case, X, A, and B are parents to C, C is a parent to Y. Y is a child node of C, C is a child node of X, A, B. Adjacent nodes are connected by a directed edge and represented with an arrow. (Pearl, 2009).

In Structural Causal Modeling (SCM), the relationships between variables associated with edges need not be linear. If all the functional relationships in an SCM are linear then it is equivalent to a SEM.

7.5.4 Model implementation

These models were implemented using the `causalgraphicalmodels` library (Barr, 2018) in Python. Each model was used to predict mean values for the constituting constructs, estimated average treatment effects. These are often used in comparing models to observed values (Palminteri, Khamassi, Joffily, & Coricelli, 2015; Palminteri, Wyart, & Koechlin, 2017; Scheibehenne & Pachur, 2015; Suppes & Zanotti, 1981; Viceconti, 2011) in model evaluation.

7.5.5 Model evaluation

7.5.5.1 Empirical evidence

7.5.5.1.1 Ethical approval

The design and the conduct of this research was approved by the Health Research Authority. Full ethical approval for the proposed design and conduct of both phases of the study has been received from the East of England – Cambridge Central Research Ethics Committee (REC reference: 17/EE/0183). The letter of HRA Approval is attached in Appendix T. Approval and confirmation of capability and capacity were also gained from the Research & Development (R&D) team at East London NHS Foundation Trust (Appendix T1).

7.5.5.1.2 Participants

Individuals who met the following criteria were eligible.

Inclusion criteria:

a) Diagnosed with HF according to current European Society of Cardiology guidelines (Ponikowski et al. 2016)

b) Older adults (>70 years old) were preferentially recruited for this study because (i) the systematic review and meta-analysis reported in Chapter 3 has identified that older adults are under-represented in research (ii) this population group is most at risk of a sedentary lifestyle (Evangelista et al., 2003; Gonzalez et al., 2004; Chien et al., 2014) (iii) the mean age of individuals affected by HF is 80 years.

c) Clinically stable: judged by health professionals at the recruitment sites and defined as having not experienced a change in symptomatic severity (NYHA class) or medical regimen in the past month (NICE, 2010)

d) Able to provide informed consent

e) Able to converse in English

If a participant was unable to read the information sheet or the questionnaire pack, those were read to them aloud.

Individuals with uncontrolled angina or with severe HF (New York Heart Association class IV) were excluded because they face severe physical limitations in performing physical activity. Anyone recommended not to exercise by a healthcare professional was also excluded.

7.5.5.1.3 Setting and recruitment

Participants were recruited from an outpatient cardiology clinic at East London NHS Foundation Trust. Individuals with HF who met the inclusion criteria were identified by the clinical team. Those who expressed interest were given the author's contact details. They then contacted the author who provided the participant information sheet (PIS, Appendix V) and informed consent form (ICF, Appendix W), which described the study in more detail. The author answered any questions and ensured that the potential participant understood the study procedure and their terms of participation. The potential participants were given sufficient time (i.e. more than 24 hours) to familiarise themselves with the study and to decide whether they would like to take part. Those who decided to take part were asked to sign the ICF. The readability of the study materials (i.e. ICF, PIS, and the questionnaire pack) was improved prior to the study using the Flesch-Kincaid readability test in Word. This metric determines the age and level of education required to comprehend written text; it is a widely recommended method in literature (Edwards, 2010).

7.5.5.1.4 Procedure

After providing informed consent, participants were given the following options to complete the baseline (time point 1) questionnaire: in person at the outpatient clinic, City University premises, at participant's home, an alternative place and time convenient to them. The participants were also given an option to complete the questionnaire by telephone or online (Qualtrics link), after receiving the questionnaire by email. In all cases, participants were given the option of asking the researcher to read the questionnaire aloud.

Each participant was given an accelerometer, shown how to use it, and asked to wear it for seven consecutive days after completing the baseline assessment (follow-up assessment; time point 2). Participants were also asked to complete a physical activity log (Appendix X) at the end of each day for the seven consecutive days. At the end of the 7-day recording, the accelerometer and physical activity log was collected by the researcher. Participants were asked to not alter their usual daily behaviour, unless advised to do so by a healthcare professional.

7.5.5.1.5 Measures

Physical activity levels were defined as the *primary outcome* of the study (dependent variable). Physical activity was operationalised as a weekly average time (mins) spent engaging in moderate to vigorous physical activity (MVPA). The demographic and clinical factors, as well as perceived barriers and enablers of physical activity are defined as *predictors of the outcome*.

7.5.5.1.5.1 Physical activity

Physical activity (MVPA) was measured using an accelerometer. Physical activity measured using self-report (7-day diary) is the secondary outcome of the study. The accelerometer provided objectively derived data on the duration and intensity of the behaviour, While the self-reports were used to assess the modality (e.g. running vs. household activities) and frequency of physical activity being performed.

7.5.5.1.5.2 Accelerometer

There are several types of objective physical activity measures, including doubly labelled water (DLW) technique, accelerometry, pedometry, heart rate monitoring (HRM), global positioning systems (GPS), and direct observation (Prince et al., 2008). Doubly labelled water (DLW) technique is used as a method to measure the average daily metabolic rate of an organism over a period of time. This is done by injecting a dose of DLW – a stable isotope tracer mixture – to an individual, and then measuring the elimination rates of the breakdown of this chemical substance in the subject over time (through regular sampling of the isotope concentrations in body water, by sampling saliva, urine, or blood). DLW technique is an invasive and laborious method. GPS introduces ethical issues by providing researchers with private information of participants' location. HRM may introduce bias, because individuals with HF often have an irregular heart rate and heart rate-based measurements may not accurately reflect physical activity levels in this clinical population. Pedometers focus only on one type of physical activity (walking) and therefore are a limited measurement. Accelerometry, which measures motion, was chosen because it eliminates these biases, ethical difficulties, and feasibility problems.

A solid-state triaxial accelerometer (ActiGraph) was used to measure motion (acceleration) in three dimensions. The employed accelerometer was medically approved, is non-obstructive, hypoallergenic, and waterproof device that can be worn on a wrist or ankle. Accelerometer is an objective measure of physical activity widely used in health research. The primary output of ActiGraph is an activity count, a measure of acceleration represented in Gs (G = 9.8 m/sec2), which are summed for each day (Hart, McClain, & Tudor-Locke, 2011). Previous research suggests that the number of days of complete data needed to reflect total physical activity behaviour in an older adult population is three days (Hart et al., 2010). More days of complete data (five days) have been found to reliably measure habitual sedentary activity (Hart et al., 2010). Physical activity was monitored for seven days due to the expected low levels of physical activity and a possible difference in the activity levels during weekends and weekdays. An accelerometer that does not give feedback has been chosen to eliminate the confounding effect of a behavioural feedback on physical activity levels (Bravata et al., 2007).

7.5.5.1.5.3 Physical activity log

Participants were asked to complete a daily physical activity log (Appendix X), listing activities from the Compendium of Physical Activities (Ainsworth et al., 2011), which are categorised as follows: household activities, transportation, conditioning, sports, leisure activities, and inactivity. The Compendium of Physical Activities is a coding scheme that classifies specific physical activity by rate of energy expenditure. It was developed to enhance the comparability of results across studies using self-reports of physical activity. The Compendium coding scheme links a five-digit code that describes physical activities by major headings (e.g., leisure time activities) and specific activities within each major heading with its intensity, defined as the ratio of work metabolic rate to a standard resting metabolic rate (MET). One MET is defined as 1 kcal/kg/hour and is roughly equivalent to the energy cost of sitting quietly. A MET also is defined as oxygen uptake in ml/kg/min with one MET equal to the oxygen cost of sitting quietly, equivalent to 3.5 ml/kg/min. Energy expenditure in MET-minutes, MET-hours, kcal, or kcal per kilogram body weight can be estimated for specific activities by type or MET intensity. The MET values for each of the activities were estimated in studies describing daily physical activity patterns of adults and studies measuring the energy cost of specific physical activities in field settings (Ainsworth et al., 2011). Therefore, the Compendium is a standardised and validated method of describing activities and specifying their intensity. Participants were asked to record the duration of the performed activities. The physical activity log takes 12 minutes to complete.

The physical activity log was chosen over other measures of physical activity that retrospectively enquire about physical activity over a period of time, in order to capture habitual physical activity which takes place throughout a 7-day period. Activity logs provide daily and detailed monitoring of the behaviour and also can be matched with data provided by the accelerometer. The physical activity log also records the modality of physical activity being performed (e.g. walking, sports), which helps to have an insight into the nature of the behaviour being recorded by an accelerometer.

Self-report methods have several limitations in terms of their reliability and validity (Shephard, 2003). Self-report methods have the capacity to over- or under-estimate true physical activity levels because of recall and response bias (e.g. social desirability, inaccurate memory) and the inability to capture the absolute level of physical activity (Shephard et al., 2003). Objective or direct measures of physical activity, such as use of accelerometer, are commonly used to increase precision and accuracy and to validate self-report measures (Prince et al., 2008). Therefore, use of both, self-reports and accelerometers, complement each other and help to overcome the limitations of each method.

7.5.5.1.6 Barriers and enablers of physical activity

An existing scale assessing the barriers and enablers to physical activity is The Determinants of Physical Activity Questionnaire (DPAQ). It is based on the TDF and is a valid and reliable measure of physical activity barriers and enablers (Taylor et al., 2013) in healthy young adults. However, the DPAQ does not capture the HF-specific constructs identified in the qualitative study. Therefore, scales suitable for older adults were selected. The choice was guided by the subjective beliefs reported in Chapter 6. The scales assessing the following domains: *Environmental Context and Resources*; *Belief about Capability*; *Goals*; *Behavioural Regulation*; *Social Influences*, *Intention*, and *Breathlessness* were selected. The questionnaire pack is supplemented in Appendix Y.

7.5.5.1.6.1 Assessment of Environmental Context and Resources

Environmental Context and Resources was elicited as a relevant to physical activity domain by the semi-structured interview study reported in Chapter 6. To assess *Environmental Context and Resources* domain this study employed the Perceptions of the Environment in the Neighbourhood Scale, PENS (Adams et al., 2013). PENS (Adams et al., 2013). PENS is a 13-item scale designed to assess the perception of walkability, ease of cycling and safety of a neighbourhood. Respondents are asked to rate their agreement on a five-point Likert scale from 'strongly agree' to 'strongly disagree'. A total score is calculated from the sum of the scores for each item. A high score represents a perception of an environment as highly supportive for being physically active. The scale has been shown to demonstrate good structural validity, internal consistency, and was predictive of objectively measured levels of physical activity.

It is important to note that "major event' – a relevant to physical activity in HF construct – is assessed using an item generated from the qualitative results presented in Chapter 6. This is due to a lack of an appropriate validated measure investigating the role of "major event' in physical activity or other behaviours.

7.5.5.1.6.2 *Assessment of Beliefs about Capabilities*

Beliefs about Capabilities domain was identified as relevant in Chapter 6, and therefore, was assessed using the 11-item Self-efficacy Scale for Exercise Behaviour, SEE (Sallis et al., 1988), which consists of two factors: a) self-efficacy for 'sticking to exercise', and b) self-efficacy for 'making time for exercise'. The scale is scored using the mean scores for each factor. The measure has been extensively validated.

7.5.5.1.6.3 *Assessment of Behavioural Regulation and Goals (behavioural)*

Behavioural Regulation and goal behavioural (*Goal* domain) was assessed using the Physical Activity Self-Regulation Scale (PASR-12), which is a 12-item scale designed to assess self-regulation, including: Self-monitoring; Goal setting; Eliciting social support; Reinforcements; Time management; and Relapse prevention. The score for each of the factors is calculated as a mean value of the scores on its respective items. The convergent validity, internal consistency, and structural validity of PASR-12 has been previously confirmed; the measure has been used in studies with older adults.

7.5.5.1.6.4 *Assessment of Goals (outcome)*

As can be recalled from the chapter outlining the qualitative study (Chapter 6), the goal to attain an outcome of physical activity (*Goal* domain), instantiated as desired functional independence, was also a relevant construct. Individuals with HF (HF) experience difficulties in their performance of activities of daily living, due to frailty (Norberg, Boman, & Löfgren, 2008), which may limit their functional independence. The most valued outcome goal of physical activity was to gain functional independence (Chapter 6). This study will utilise PRISMA 7 questionnaire in the assessment of functional independence. PRISMA 7 is a self-reported measure designed to evaluate the extent of frailty in older population and people with chronic conditions (Turner & Clegg, 2014). In particular, since the qualitative study identified that people engage in the prescribed physical activity to be able to get on with everyday life independently from others(Chapter 6), the participants are classified into two subgroups: those who do not need others' help on day-to-day basis and those who do.

This is operationalised using the item ('Do you need someone to help you on a regular basis?'), which indicates whether the state of desired functional independence is satisfied.

7.5.5.1.6.5 Assessment of Social Support

Social Influences was identified as a relevant domain in Chapter 6. This domain was assessed using the Social Support Scale for Exercise Behaviour, SSE (Sallis et al., 1988), which is a 12-item scale designed to assess social support specific to exercise behaviour received from family and friends. Respondents rate the frequency of family and friends' exercise-related activities and discussions on a 5-point scale, ranging from 1 (none) to 5 (very often). The scale has two factors: friends and family, a score for each factor is a mean value of each items' response. The total score is the sum of scores for both factors. The structural validity and internal consistency of the measure has been supported, the score of the measure is correlated with physical activity levels. The scale has been used in studies with older adults.

The questionnaire pack took 20 minutes to self-administer when piloted for use by older adults (>70 years, *N*=3). The feedback from the three individuals was used to change the outlook and phrasing of the pack.

7.5.5.1.6.6 Assessment of Dyspnoea

Chapter 6 reported that breathlessness shaped beliefs within domains such as *Beliefs about Capability* and *Beliefs about Consequences*, as well as affected how participants planned their physical activity (*Behavioural Regulation*). Breathlessness was measured with the Dyspnoea-12 (Yorke et al., 2010). The Dyspnoea-12 includes two empirically suggested dimensions – physical and affective aspects of dyspnoea, which were both identified as relevant in Chapter 6. The scale was also developed from the descriptors of dyspnoea provided by individuals with COPD and HF (Yorke et al., 2010), making it a relevant measure to this study. The Dyspnoea-12 has 12 items rated on a 4-item Likert scale from '*None*' to '*Severe*'. Dyspnoea-12 has good internal reliability, structural validity, convergent validity and good test - retest reliability. The score ranges from 0 to 36, where 0 is no breathlessness and 36 maximal breathlessness.

7.5.5.1.6.7 Assessment of Illness Identity (Breathlessness symptom identity)

Participants in the qualitative study (Chapter 6) consistently reported breathlessness as a barrier to physical activity, however, sometimes in conjunction with other symptoms such as chest pain, fatigue, and tight chest. Participants did not link breathlessness symptom to their HF and reported the symptoms as a general every-day experience and an overall somatic state. To further investigate if breathlessness and other HF-related symptoms were major barriers only when the symptoms were linked to HF, we will assess whether participants linked these symptoms to HF using Illness Perception Questionnaire (revised; IPQ-R; Moss-Morris 1998) symptom identity subscale. To also assess if the frequency and severity of the symptoms impacted whether the symptoms acted as barriers to physical activity, symptom frequency and symptom severity was assessed.

A subscale from t he IPQ-R questionnaire - symptom identity - was designed to assess perceptions of symptoms and lists 14 symptoms. The items are rated as a yes/no response. As expressed by the authors of the subscale, it can be changed to reflect variations in symptoms within study samples, and so the item 'sore eyes' was replaced with "shortness of breath.", and 'my illness' was replaced with 'HF'. These amendments were previously made and validated for use in HF (Hallas et al., 2011).We also replaced 'sore throat' with 'chest pain' and 'upset stomach' with 'tightness in the chest'. We also added "Low Mood' and 'Other' to give an opportunity to participants to report other symptoms. IPQ-R has good inter-rater reliability and was previously validated for research in HF (Hallas et al., 2011). Each symptom's frequency is assessed on a 4-point Likert scale from 'Almost never' to 'Almost all the time' and symptom severity is assessed on a 4-point Likert scale ranging from 'Not applicable' to 'Severe/Debilitating'.

7.5.5.1.6.8 Assessment of Optimism

Optimism modulated whether a domain was perceived as a barrier or an enabler as reported in Chapter 6. To assess Optimism Life Orientation Test -R (LOT - R, Carver 2013) was employed. LOT-R is a widely used, reliable and valid measure of optimism. The LOT-

R is a 10-item scale which consists of Optimism and Pessimism scales and includes three items assessing optimism, three assessing pessimism, and four fillers. The respondents indicate the extent to which they agreed with each item on a 5-point Likert scale that ranges from 'I agree a lot' to 'I disagree a lot'. LOT-R is a valid and a reliable measure. LOT-R has good structural validity and convergent validity (Glaesmer et al., 2011; Steptoe et al., 2006).

7.5.5.1.6.9 Assessment of Intention

Intention, although was not identified as a relevant barrier and enabler directly related to physical activity, it was included in causal beliefs about how barriers and enablers interact (Chapter 6). Due to the lack of a validated scale assessing *Intention* to engage in physical activity, the belief statements describing the domain and constituting constructs were utilised in the development of the items tapping into the influence of these domains on physical activity. The items designed to assess Intention were modelled from previously existing measures (Presseau et al., 2013). The focal intention to engage in physical activity was measured for one week's period (i.e. 'I intend to engage in some form of physical activity in the next week').

7.5.5.1.6.10 Assessment of Beliefs about Consequences and Health Event

The Beliefs about Consequences, and barriers associated with the Major event were HF-specific. Therefore, in this study, a measure of barriers and enablers of physical activity in HF has been developed using items generated from the semi-structured interviews study.

The Barriers and Enablers of Physical Activity in HF (BEPA-HF) questionnaire includes 53 items based on the 78 belief statements covering the 14 TDF domains. The development of the BEPA-HF scale is reported in Appendix Z. Participants were asked to rate their agreement with each belief statement on a 6-point Likert scale (Strongly Disagree (1) – Strongly Agree (6)). An aggregate score of the items within each domain were calculated. The individual item scores quantified corresponding constructs. The Beliefs about Consequences were assessed using the following BEPA-HF items:

Positive outcome expectancy[1]	Enabler	Physical activity improves my general health
Risk perception/Concerns	Barrier	Physical activity brings on my heart failure symptoms (e.g. breathlessness; tight chest; fatigue; swollen legs)
Positive outcome expectancy[1]	Enabler	1. I engage in physical activity because it makes me feel more cheerful 2. Not engaging in physical activity makes me feel low
Risk perception/Concerns	Barrier	Being physically active is dangerous because it puts a strain on my heart
Positive outcome expectancy[1]	Enabler	Physical activity helps to improve the strength of my heart
Risk perception/Concerns	Barrier	Physical activity brings on my heart failure symptoms (e.g. breathlessness; tight chest; swollen legs; extreme fatigue)

The major event (barrier) was assessed using the following BEPA-HF items: '*I do less physical activity than I used to, because of a recent major health- related event. (e.g. hospitalisation, surgery, heart attack)*'.

The major event (enabler) was assessed with the following item: '*I do more physical activity than I used to, because of a recent major health- related event. (e.g. hospitalisation, surgery, heart attack*)'.

7.5.6 Feasibility

The recruitment rate for the present study was exceptionally low. A total of six (*N*=6) participants expressed their interest in the study to the clinical team in five months. Only three (*N*=3) met with researchers and were recruited. COVID-19 made continued recruitment impossible. Despite the attempt to recruit older adults (>70 years old) the mean age of the sample was 60.3 years. Older adults consistently declined the invitation to take part.

All participants (*N*=3) asked for the questionnaires to be read to them out loud by the researcher. As a result, the questionnaire assessment took 45, 60 and 75 minutes each. This is at least twice as long as what was estimated during the pilot administration of the questionnaire pack. None of the participants opted for the online scale completion.

Therefore, appropriate timeline and resources (i.e. sites) should be allocated for the recruitment of a sample size sufficiently large for significance testing. The required sample sizes are recommended in the power analysis results section below.

The accelerometer non-wear time was substantial. Only one participant wore the accelerometer for the total intended duration of seven days. One participant did not wear the accelerometer for six out of seven days, and another for two out of seven days, respectively. Therefore, the mean MVPA (mins/day) was chosen as the primary outcome instead of the total number of activity bouts. Physical activity log was used to calibrate the accelerometer data, and suggested that individuals engaged in walking as a leisurely activity and walking for daily tasks.

The appropriate methodology (Gelman et al., 2003) was used to model physical activity behaviour as informed by Chapter 6. Three models (*N*=3003) were sampled using Monte Carlo Simulation as will be described in the model implementation section.

Due to the extremely small sample size (*N*=3) being included in this study, appropriate methods for hypothesis testing in a small sample (Gelman, Carlin, Stern, & Rubin, 2003; Shikano, 2019; van de Schoot & Miočević, 2020) were then applied. The sampled models as informed by qualitative study (Chapter 6) were compared to the observed data (*N*=3) using Bayesian hypothesis testing (Klaassen, 2020).

7.5.7 Statistical analysis

7.5.7.1 *Monte Carlo Simulation*

Samples (N_{Sim}=3003) from the prior distribution associated with each model (HAPA, Auxiliary, MB-MF-Pavlovian) were obtained by sampling from appropriate distributions for the exogenous variables (implantable device, age, comorbidity, social support). Major event was sampled from a binomial (66%; percentage of heart attack in HF in 2018; British National HF Audit, 2018) and age and comorbidity, social support, and breathlessness were sampled from a normal distribution. The normal distributions were centred on the mean values of these variables as reported in the audit (British National HF Audit, 2018): age mean = 80.1 (*SD* = 11.2), comorbidity mean = 4.3 (*SD* = 2.3). Social support was obtained from a study included in the systematic review (mean = 24.1, *SD* = 7.7; Gallagher et al., 2011), and levels of breathlessness in HF from a study by Yorke et al. (2010).

7.5.7.2 *Expected average effects*

From sampled datasets (N_{sim}) and observed sample *(N, observed)* the expected average effects (AE) were calculated as the standardised mean difference (*SMD*) in time spent engaging in MVPA (mins/day), between those who scored above the mean value for the given variable (i.e. *Intention*) and below the mean value. For binary variables (i.e. Functional Independence, Implantable Device, Physiological State), AE was calculated as SMD between the two groups (i.e. Implantable Device = 1 and Implantable Device = 0). Observed (n=3) and predicted by each model AEs were estimated using the function `ate` in the `causalgraphicalmodels` library.

7.5.7.3 Bayesian hypothesis testing

In a Bayesian framework[13], the probability of each model given the data was calculated. Each Hypothesis described in Objectives entails a statement about the posterior probability of one model being greater than another. To assess this, the posterior odds in favour of each model (Model 1) over each other model (Model 2) was calculated (Gu, Hoijtink, Mulder, & Rosseel, 2019; Klaassen, 2020). The posterior model probabilities (Hijtink et al., 2012) are therefore the representations of the support in the data for each model (Model 1) over another (Model 2).

The Bayes Factor is a ratio comparing two models. The scale for Bayes factor interpretation was adopted from Kass & Rafftery (1995). A Bayes factor above 1 suggests that the data supports Model 1 over Model 2. A Bayes Factor smaller than 1 indicates that the data supports Model 2 over Model 1. A Bayes Factor of 1 suggests that models are equivalent.

Model comparison was performed using the `bain` library in **R** (Gu et al., 2019). The Bayes factor was computed to quantify the relative evidence in the data in favour of either model described by HAPA, Auxiliary model, or Pavlovian model.

7.5.7.4 Power analysis

The simulation for power analysis was carried out in `SSDbain` library in **R**. The power calculation is based on a Monte Carlo simulation from the observed data (*N*=3). The Bayes Factor (BF) was plotted for each simulated sample size (N=1, …, 5000).

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[13] Bayesian hypothesis testing was used instead of frequentist significance testing (p-value), due to the extremely small study sample (n=3).

The sample size is estimated as follows. A total of 409 participants are required to obtain BF>1 indicating that HAPA model is preferred over the null model; 172 are required to obtain BF>1 indicating that the Auxiliary model is preferred over the null model; 128 – that MB-MF-Pavlovian integrated with HAPA is preferred over the null model, and 86 – that MB-MF-Pavlovian integrated with the Auxiliary model is preferred over the null model.

7.6 Results

7.6.1 Participant characteristics

The total sample size included three participants (*N*=3).

The study participants, on average, engaged in 46.05 (*SD* = 20.99) minutes of moderate to vigorous physical activity a day. They were 60, 60, and 71 years old each and were diagnosed with diabetes Type 2 (*N* =2), hypertension (*N* =2), and arthritis (*N* =1). The mean (*SD*) values are reported in Table 7.1.

Table 7.1. Participant Characteristics

	Mean	SD
Age	60.33	8.58
Comorbidity (perceived barrier)	5.33	0.47
Implantable Device (present)	77%	
Number of comorbidities	1.67	0.58
Breathlessness	17.66	6.65
Illness Identity	One out of three participants identified breathlessness as a HF symptom	
Optimism	13	4.59
Intention	3.67	0.47
Action Self-efficacy	4.33	0.72
Risk Perception associated with physical activity	4.17	0.62
Outcome Expectancies (positive)	5.17	0.72
Volitional Self-efficacy	4.00	1.22
Action Planning	3.33	1.31
Coping Planning	3.67	1.25
State (PRISMA-7: functional independence/frailty)	Two (*N* = 3; 77%) said they do not need help from others	
Goal (behavioural)	2.33	0.47
Health Event (perceived barrier)	3	2.65
Physiological State	3.00	2.16
MVPA (mins/day)	46.05	20.99

7.6.2 Model specification

7.6.2.1 Specification common to all models

The exogenous variables for all models were: age, comorbidity, and implantable device. The auxiliary model also included the following exogenous variables: social support and major event. The MB-MF-Pavlovian model included breathlessness. The mean and standard deviation for age, comorbidity, and implantable device were specified as reported in the National HF Audit (2018). The probability of individuals with HF who experienced heart attack was specified as reported in the National HF Audit (2018). The mean (*SD*) for breathlessness was specified as reported in a study (*N*=102) investigating levels of breathlessness in HF (Yorke et al., 2010). The mean (*SD*) for social support was specified as reported in a study (*N*=333) identified by the systematic review (Chapter 4: Gallagher et al., 2011).

Only standardised means were implemented in obtaining distributions for all variables in the models following methods developed by Gelman and colleagues (Gelman et al., 2003). and u coefficients describing relationship between self-efficacy and age, comorbidity, implantable device were estimated from the mean (*SD*) and correlation coefficients reported in a study identified by the review (Chapter 4: Dontje et al., 2014).

7.6.2.1.1 The baseline model

The baseline model was HAPA (Schwarzer 2008; Figure 1). Zhang et al., (2019) carried out a meta-analysis of studies evaluating empirical support for HAPA. As the result, HAPA was amended to only include constructs and mechanisms supported by the empirical evidence (Zhang et al., 2019). The new truncated HAPA that Zhang et al. (2019) formulated is shown in Figure 2.

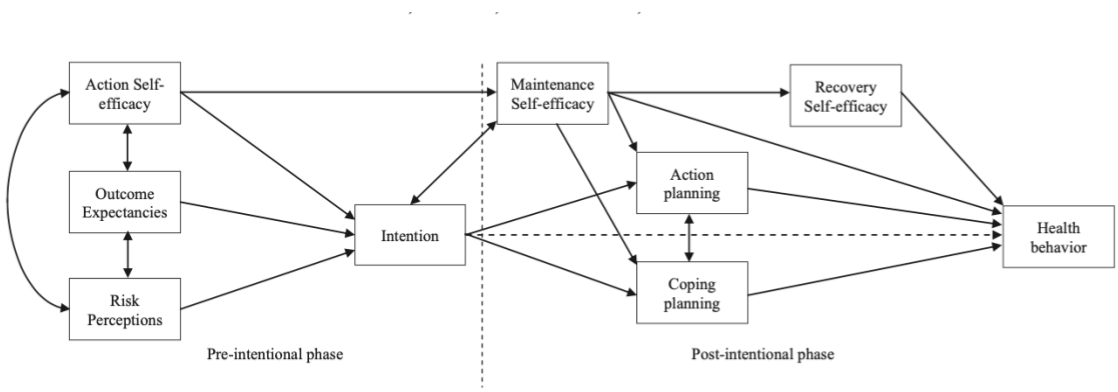


Figure 7.2. HAPA model (from Zhang, Zhang, Schwarzer and Hagger 2019).

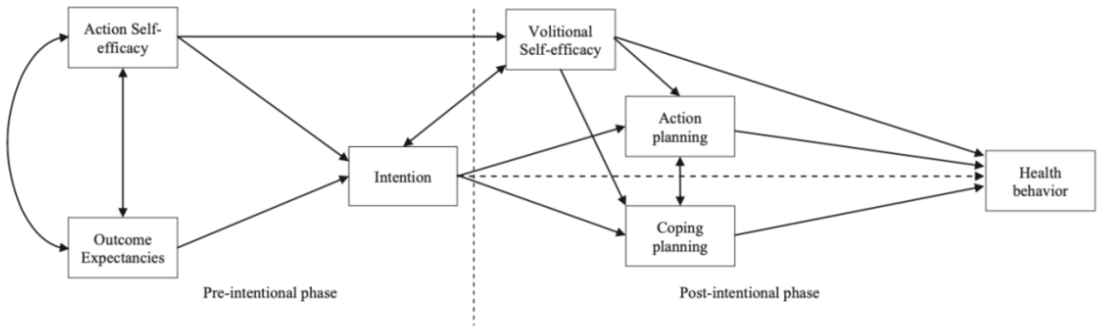


Figure 7.3. Truncated HAPA model following data confrontation (from Zhang et al., 2019).

Note: The HAPA was confronted with empirical data in a series of observational studies. The latest meta-analysis indicates that 95 studies evaluated the complete set of HAPA constructs as well as the structure of constructs' relationships as stipulated by HAPA. A meta-analysis of 95 observational studies investigating the association between HAPA constructs and behaviour (Zhang et al., 2019) provides compelling support for the truncated HAPA model. As the result with data confrontation in this meta-analysis (Zhang et al., 2019), risk perception was deemed a redundant construct and maintenance and recovery self-efficacy were unified into volitional self-efficacy

For the purpose of this study, HAPA was further truncated into a directed acyclic graph (DAG, Figure 3). This was necessary because bidirectional relationships are undefined in structural causal modeling (SCM). HAPA is described as SEM below.

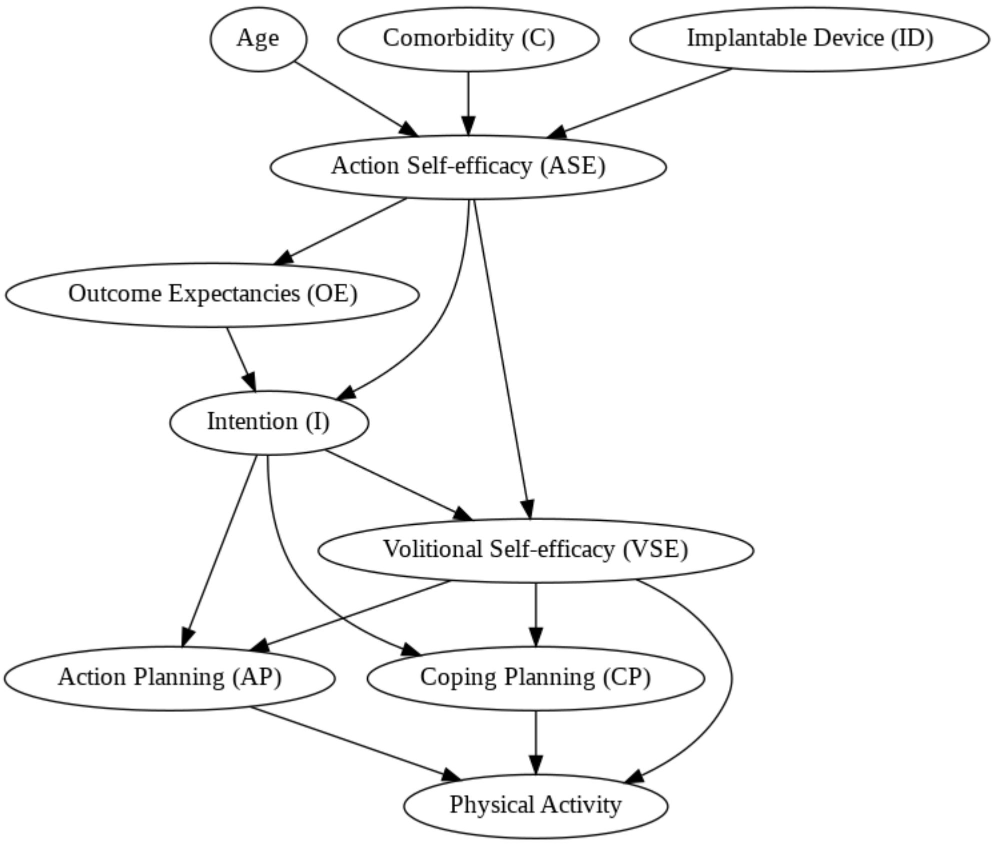


Figure 7.4. The directed acyclic graph (DAG) representing the HAPA model.

HAPA Structural Equation model:

Measurement model

I ~ set of relevant psychometric scale items

ASE ~ psychometric scale items

OE ~ psychometric scale items

VSE ~ psychometric scale items

CP ~ psychometric scale items

AP ~ psychometric scale items

Structural model

$$ASE = u_{ASE} + w_{age-ASE}\, Age + w_{C-ASE}\, C + w_{ID-ASE}\, ID$$

$$OE = u_{OE} + w_{ASE-OE}\, ASE$$
$$I = u_I + w_{ASE-I}\, ASE + w_{OE-I}\, OE$$
$$VSE = u_{VSE} + w_{I-VSE}\, I + w_{VSE-I}\, ASE$$
$$CP = u_{CP} + w_{I-CP}\, I + w_{VSE-CP}\, VSE$$
$$AP = u_{AP} + w_{I-AP}\, I + w_{VSE-AP}\, VSE$$

$$PA = u_{PA} + w_{AP-PA}\, AP + w_{CP-PA}\, CP + w_{VSE-PA}\, VSE$$

Where: *OE* is Outcome Expectancies, *ASE* is Action Self-Efficacy, *I* is Intention, *VSE* is Volitional Self-Efficacy, CP is Coping planning, *AP* is Action Planning, *PA* is physical activity; PA is physical activity; w's are parameters describing the corresponding linear relationship; and u's are constant parameters.

The endogenous latent variables and the relationships among them for the baseline model (HAPA) were specified as described in Table 7.2.

Table 7.2. Specified parameters for the HAPA model.

X	***Y***	***u (intercept)***	***w (coefficient)***
Age	ASE	2.25	-0.28
Comorbidity	ASE	2.25	-0.28
Implantable Device	ASE	2.25	-0.28
OE	ASE	0.34	0.320
ASE	Intention	0.418	0.295
Intention	Intention	0.349	0.235
ASE	VSE	0.403	0.480
VSE	Intention	0.307	0.049
Intention	AP	0.398	0.305
VSE	AP	0.378	0.314
Intention	CP	0.323	0.194
VSE	CP	0.400	0.343
AP	MVPA	0.305	0.087
CP	MVPA	0.294	0.051
VSE	MVPA	0.283	0.144

Note 1 : The intercepts and slopes for age-ASE, comorbidity-ASE and implantable device-ASE (from Dontje et al., 2014); no detail available); The intercepts and slopes specified for the HAPA model(From Zhang et al., 2019).

7.6.2.1.2 MB-MF-Pavlovian model

MB-MF-Pavlovian model (Dayan & Berridge, 2014) is a model widely used in computational psychiatry (O'Doherty, Cockburn, & Pauli, 2017) to describe both human and animal behaviour. It is normally implemented algorithmically as a dynamic model. However, in this thesis it will be considered as an equivalent SEM for consistency with HAPA.

MB-MF-Pavlovian (Dayan & Berridge, 2014) is rendered as a directed acyclic graph (DAG, Figure 4). According to MB-MF-Pavlovian model (Dayan & Berridge, 2014) humans evaluate the current circumstance or state (FI): satisfactory attainment of functional independence in HF. She produces an evaluation under the conditions of an affective or somatic state (e.g. dyspnoea, fatigue, joy). The human then estimates a reward based on the circumstance (*FI*) and the motivational state (*m*) which defines the choice of action (*A*). In the present study actions are as follows: increase the current level of physical activity, maintain the same level, or decrease the current level of physical activity.

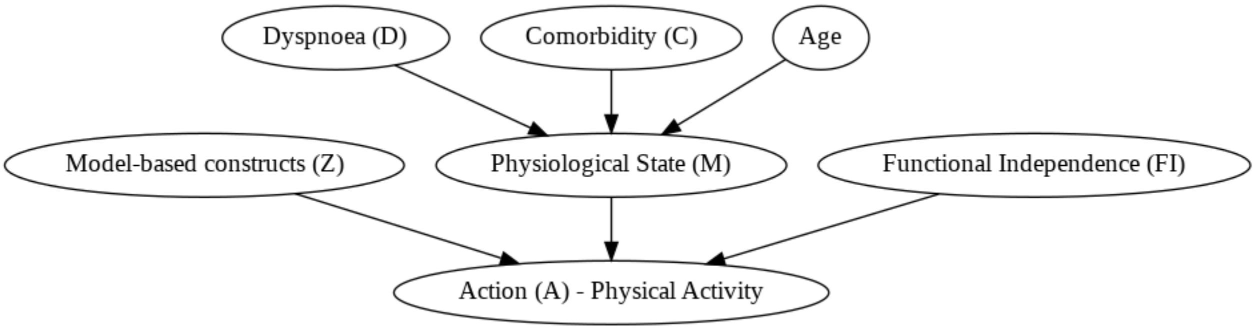


Figure 7.5. The MB-MF-Pavlovian model in HF described in a *DAG*.

MB-MF Pavlovian as a Structured Causal Model

MB-MF Pavlovian as a Structured Causal Model

$M = f_1$(Dyspnoea, Age, Comorbidity)

$$M = \begin{cases} 1 & if\ D \geq 17\ \wedge\ Age > 60\ \wedge C \geq 5 \\ 2 & if\ D \geq 17\ \wedge Age \leq 60\ \wedge C \geq 5 \\ 2 & if\ D \geq 17\ \wedge Age \leq 60\ \wedge C < 5 \\ 3 & if\ D \geq 17\ \wedge Age > 60\ \wedge C < 5 \\ 4 & if\ D < 17\ \wedge Age \leq 60\ \wedge C < 5 \\ 5 & if\ D < 17\ \wedge Age > 60\ \wedge C \geq 5 \\ 5 & if\ D < 17\ \wedge Age > 60\ \wedge C < 5 \\ 6 & if\ D < 17\ \wedge Age \leq 60\ \wedge C \geq 5 \end{cases}$$

$FI \in \{0, 1\}$, where 0 is low functional independence (undesirable state);
1 is not low functional independence (desirable state).

$$FI = \begin{cases} 0 & if\ PRISMA7\ item\ 2\ score = 0 \\ 1 & if\ PRISMA7\ item\ 2\ score = 1 \end{cases}$$

Where, Prisma-7 Item 2 is: '*Do you need someone to help you on a regular basis?*' And set to 0 in 52.7% of the sample for the simulated models (Dunlay et al., 2015).

$f_3(M,\ FI)$

$A \in \{0, 1, 2\}$, where 0 engage in minimal/no physical activity; 1 – maintain the same level of activity; and 2 is 'engage in more regular physical activity'.

$$A = \begin{cases} 2 & if\ FI = 0\ \wedge\ M \geq 4 \\ 1 & if\ FI = 1\ \wedge\ M \geq 4 \\ 0 & if\ FI = 1\ \wedge\ M < 4 \\ 0 & if\ FI = 0\ \wedge\ M < 4 \end{cases}$$

7.6.2.1.3 Auxiliary model

The auxiliary hypothesises resultant from the qualitative study are formally specified in a directed acyclic graph (*DAG*, figure 6), as a structural causal model, and as a structural equation model (SEM; Equation 4).

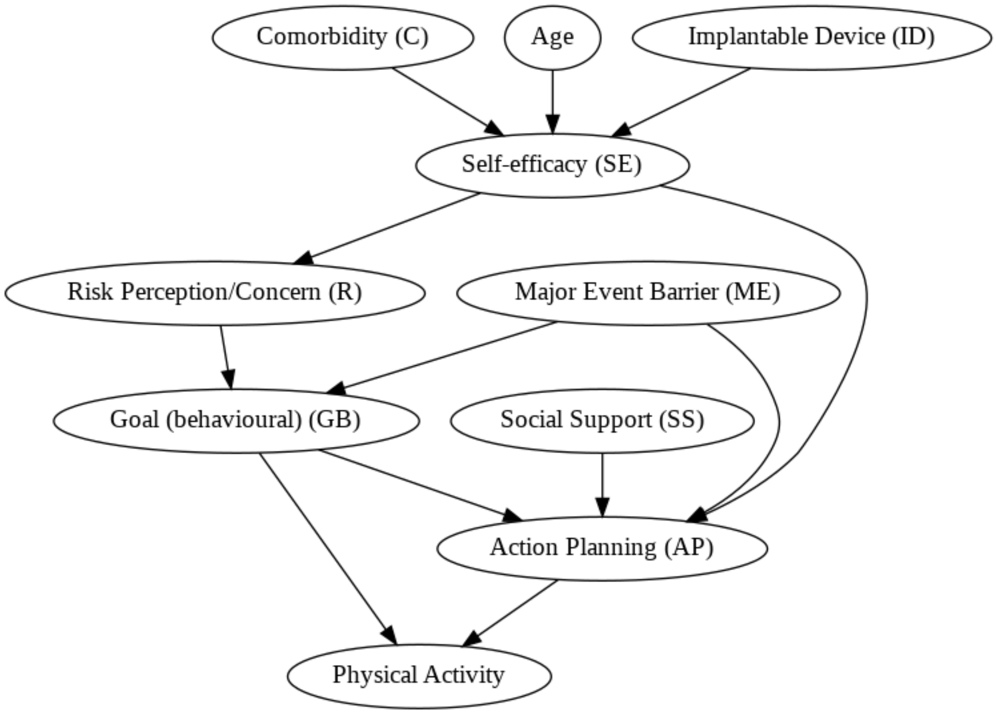


Figure 7.6. An Auxiliary model based on the qualitative study described in a directed acyclic graph (DAG).

Auxiliary Structural Causal model (4)

Auxiliary model is a Structural Causal Model, with observations N:

$$SE = f(ID, Age, C)$$
$$R = f(SE)$$

GB $= f(ME, R)$

$AP = f(SS, GB, SE, ME)$

$$PA = f(AP, GB)$$

Structural Equation model (4)

Measurement model:

ASE ~ psychometric scale items

R ~ psychometric scale items

VSE ~ psychometric scale items

CP ~ psychometric scale items

AP ~ psychometric scale items

Structural model:

$SE = u_{VSE} + w_1 ID + w_3 Age + w_3 C$

$$R = u_R + w_4 SE$$
$$GB = u_{GB} + w_6 ME + w_7 R$$
$$AP = u_{AP} + w_9 GB + w_9 SE + w_{10} ME + w_{11} SS$$
$$PA = u_{PA} + w_{12} AP + w_{13} GB$$

Where: *R* is Risk Perception, *AP* is Action Planning, SS is social support, GB *is Goal (behavioural), PA* is physical activity; $w_{1...11}$ is a parameter describing the corresponding linear relationship; and *u* is a constant parameter (exogenous to the model). PA is physical activity; w1…n is a parameter describing the corresponding linear relationship; and u is a constant parameter (exogenous to the model).

Parameters pertaining to the endogenous variables in the Auxiliary model were specified as follows. All w values were set to 1/n where n = the number of variables. All u (intercept) values were set to 0.

7.6.3 Model Implementation results

Bayesian hypothesis testing was carried out to evaluate which model is most **parsimonious** and **fits** the data (N=3) most closely.

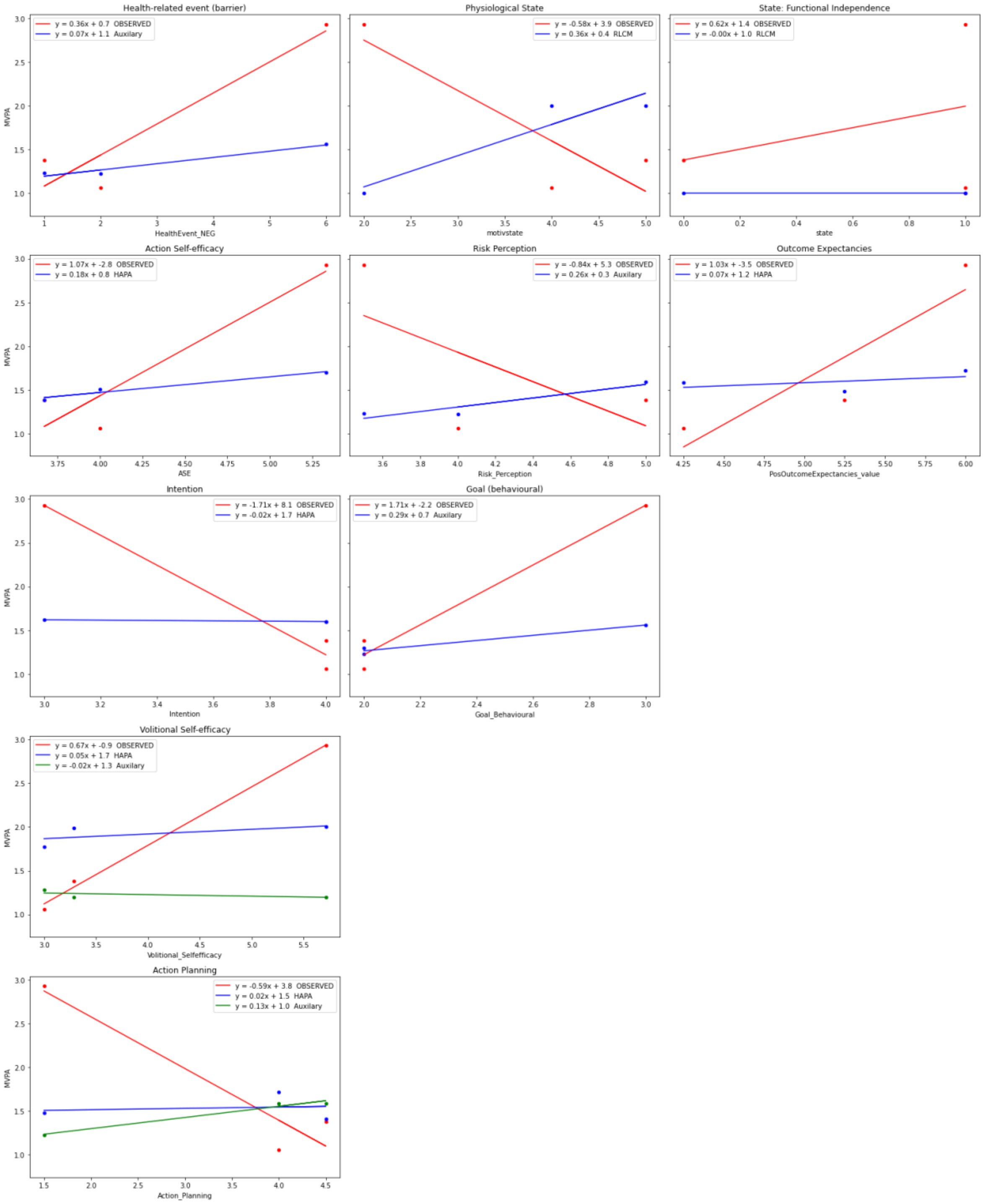


Figure 7.7. Samples from the prior distribution associated with HAPA, Auxiliary, and MB-MF-Pavlovian models plotted next to observed data points.

Note 1: The observed (N=3, in red), and predicted time (mins) spent engaging in moderate to vigorous physical activity (MVPA) at different values of health event barrier, physiological state and functional independence (state), action-self-efficacy, risk perception, outcome expectancies, intention, goal (behavioural), volitional self-efficacy, and action planning as observed (red), according to HAPA, Auxiliary, and MB-MF-Pavlovian models.

At the corresponding value for each barrier or an enabler, the value for the standardised MVPA (mins/day) predicted by each model are also plotted in an alternative colour. As can be seen from the plots the trend in observed MVPA (mins/day) follows the trend predicted by HAPA for constructs such as *Positive Outcome Expectancy*, *Action Self-efficacy* and *Volitional Self-efficacy.*

7.6.4 Potential barriers to physical activity in HF

Lower levels of MVPA (mins/day), as measured using triaxial accelerometer, were observed for the following variables: *Intention*, *Action Planning*. Medium to large negative effects were observed for *Risk Perception* (Table 7.3).

7.6.5 Potential enablers of physical activity in HF

Health Event (barrier), a positive *Physiological State* (i.e. lower than the average level of breathlessness, smaller than the average number of comorbidities), as well as *Positive Outcome Expectancies*, *Functional Independence* (i.e. not requiring help from others, PRISMA-7: Item 2), *Goal (behavioural), Action Self-efficacy*, *Volitional Self-efficacy* were associated with a higher level of MVPA (mins/day), as measured using triaxial accelerometer (Table 7.3).

Table 7.3. The expected AE in time (mins) spent engaging in moderate to vigorous physical activity (MVPA) associated with each construct as observed (*N*=3) and predicted by HAPA, Auxiliary, and MB-MF Pavlovian model (estimated for *N*=3003).

Construct	Expected average effect
Implantable Device (observed, *N*=3)	0.75
Age (observed, *N*=3)	-1.34
Comorbidity (observed, *N*=3)	-0.76
Intention	
Observed *SMD*	-2.10
Predicted by the HAPA model	0.12
Action self-efficacy	
Observed *SMD*	2.09
Predicted by the HAPA model	0.06
Risk perception (Neg. Outcome expectancies of the behaviour/concerns)	
Observed *SMD*	-0.80
Predicted by the Auxiliary model	0.13
Volitional Self-efficacy	
Observed *SMD*	2.09
Predicted by HAPA	0.08
Action planning	
Observed *SMD*	-2.09
Predicted by the Auxiliary model	0.38
Predicted by HAPA	0.07
Goal	
Observed *SMD*	2.08
Predicted by the Auxiliary model	0.39
Health event barrier	
Observed *SMD*	-0.39
Predicted by the Auxiliary model	-0.44
Physiological state	

Observed *SMD*	1.50
Predicted by the Pavlovian model	0.84
State (desired: Functional Independence)	
Observed *SMD*	-1.50
Predicted by the Pavlovian model	-0.44
Positive outcome expectancies	
Observed *SMD*	1.38
Predicted by HAPA	0.06

Note 1 : The expected average effect is estimated without adjusting for all variables that satisfy back-door criteria (Pearl, 2009), as explicated by the corresponding model (i.e. Pavlovian, HAPA, Auxiliary models). This is because the observed effects could not be adjusted due to the extremely small sample size (*N*=3).

7.6.6 Hypothesis testing results

Because an extremely small sample size was reached (*N*=3), Bayesian hypothesis testing was implemented instead of significance testing (p-value). The results of the Bayesian hypothesis testing are reported in Table 7.4. The Bayes Factor indicates that after observing data (*N*=3), the probability of Goal (behavioural) to predict MVPA (mins/days) is higher than that of Intention (Bayes Factor: 3.56 vs 0.29). HAPA was not preferred over null model as indicated by a Bayes Factor of 0.76. The results of the ordered hypothesis testing are summarised in Figure 7.7. MB-MF-Pavlovian model was more **parsimonious** and **fitted** the data (N=3) more closely than the Auxiliary model, and the Auxiliary model fitted the data better than the HAPA model.

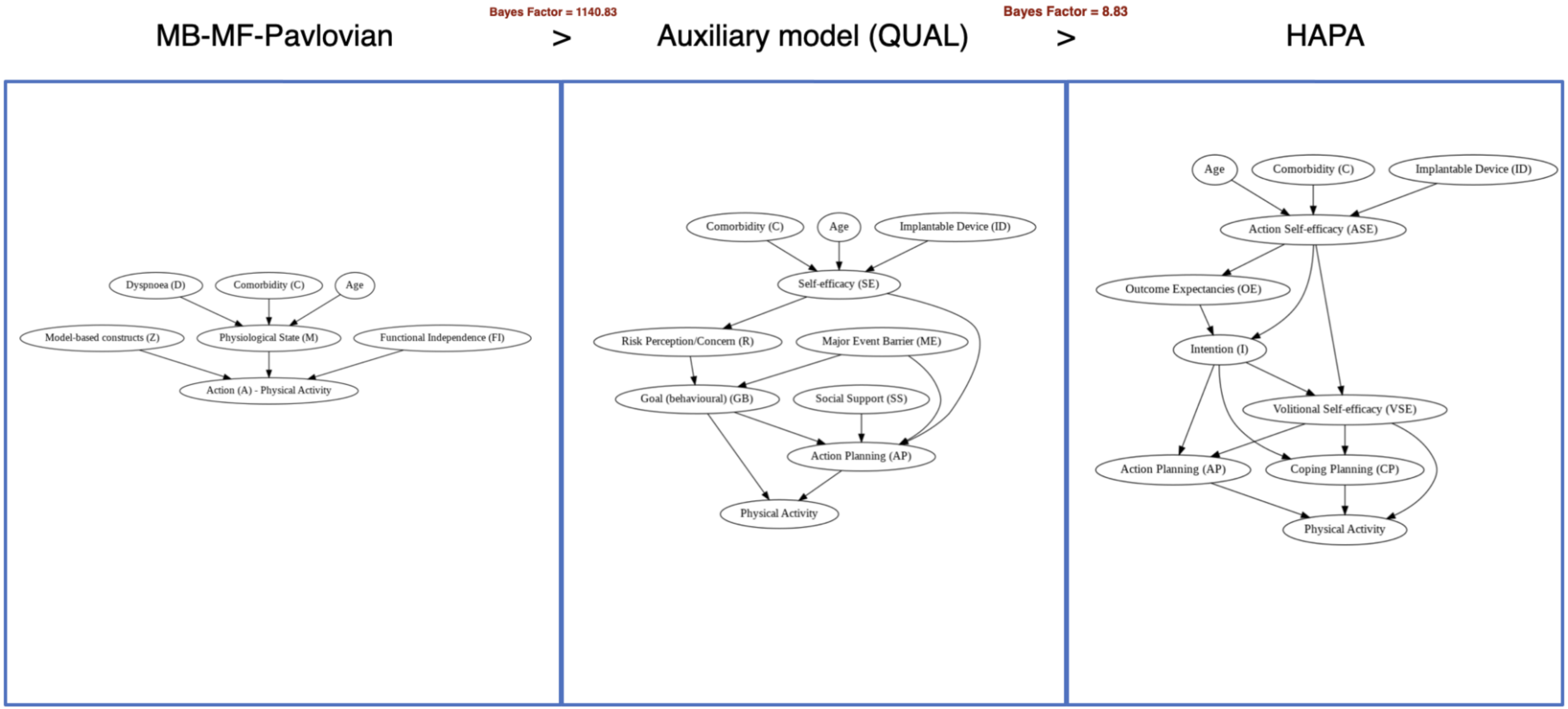


Figure 7.8. Bayesian Hypothesis Testing results: Bayes factor (parsimony and goodness of fit ratio) comparing three proposed models.

The MF-MB-Pavlovian model alone is a better model than either Auxiliary or HAPA model, according to the Bayes Factor values, 1140.83 and 2466.63 respectively. This is due to the higher parsimony (i.e. smaller number of constrained parameters explicating the relationships between each variable – barriers or enablers and MVPA (mins/day)) of the Pavlovian model compared to other models.

When, equally parsimonious models are compared, it is suggested by the Bayes Factor that the Auxiliary model is more likely to be supported by the data (N=3) than HAPA. Similarly, the Auxiliary model combined with the MB-MF-Pavlovian model is more likely to be supported by the data (N=3) than the HAPA combined with the MB-MF-Pavlovian model.

The power analysis indicated that the following sample sizes are required to establish the statistical significance of the models in explaining physical activity in HF: 409 participant to test HAPA, 172 to test the Auxiliary model, 128 – MB-MF-Pavlovian integrated with HAPA, and 86 – MB-MF-Pavlovian integrated with the Auxiliary model.

Table 7.3. A preference of Model 1 over Model 2 as described by Hypothesis 1, Hypothesis 2, Hypothesis 3, and Hypothesis 4.

Model comparison		
Model 1	**Model 2**	**Bayes Factor**
Intention	*Goal*	0.29
Goal	*Intention*	**3.56**
MB-MF Pavlovian	HAPA	2466.63
HAPA	MB-MF Pavlovian	0.0004
MB-MF Pavlovian	Auxiliary model	**1140.83**
Auxiliary model	MB-MF Pavlovian	**0.0008**
HAPA	Auxiliary model	0.113
Auxiliary model	HAPA	**8.83**
MB-MF Pavlovian and HAPA	MB-MF Pavlovian and Auxiliary model	0.12
MB-MF Pavlovian and Auxiliary model	MB-MF Pavlovian and HAPA	8.617

7.7 Discussion

Before discussing the results of the present study it should be noted that only an extremely small sample size was reached (*N*=3), raising concerns about the feasibility of a cross-sectional study in this population. The present study aimed to recruit older adults with HF. It is well-established that older adults (>65) with HF refuse to take part in research studies to a greater extent than younger patients (Harrison et al., 2016). Older individuals living with HF experience high levels of frailty (Norberg et al., 2008) and therefore may not wish to take part in a study involving wearing an accelerometer. Previous research indicated that to recruit a small number of HF patients screening of a large sample is required (Pressler et al., 2008). Due to ethical considerations, screening was performed by the healthcare team and not by the author of the thesis. Healthcare teams are exceptionally busy and protective of their patients. They may not wish to overburden patients who experience greater health issues or older age. These issues may have impeded the initial recruitment.

In addition, older adults prefer studies to be carried out over the phone (Hoffmann et al., 2013). This was not possible, as the present study involves demonstration of an accelerometer. Low health literacy is a recruitment barrier that disproportionately affects older adults (Berkman et al. 2011). This may result in low recruitment rates. In the present study, the readability of the study materials was improved using appropriate methods to promote greater engagement. Individuals living with HF may also be concerned with privacy and lack trust, as was suggested by a study on the reasons for refusing to take part (Harrison et al., 2016). The author of this thesis was not a part of any potential participants' healthcare team, which may have deterred them. It is recommended to address privacy concerns and build closer relationships with the healthcare team in order for the researcher to be present at the clinic. In the present study the research was contacted once someone expressed an interest. They were not present on the site – due to the large workload of the healthcare team. Other concerns for feasibility include the following. The accelerometer devices are costly therefore appropriate funding should be available. Also, due to the low recruitment rate, a multi-centre study should be considered. All these issues should be taken into account before embarking on a large cross-sectional study.

All the aforementioned recruitment challenges are expected for studies recruiting individuals with HF in the absence of an ongoing pandemic. In addition to these, the COVID-19 pandemic prevented further recruitment. The population of interest's HF diagnosis and age presents high mortality and health complication risks following COVID-19 contraction. Therefore, they are shielding. This is because the study may involve face-to-face meetings, as participants were reluctant to complete the questionnaire online and instead preferred for the researcher to assist in responding to the questionnaire. The study also requires demonstration of an accelerometer. Under these circumstances, recruitment is not feasible.

7.7.1 Developing a falsifiable model of barriers and enablers to physical activity in HF

Given the extremely small sample size, interpretations of Bayesian hypothesis testing and estimated average effects should be considered with caution. However, the implemented methods for statistical analysis offer a valuable contribution in the following. Computational modelling is advocated for its use in behaviour change research and intervention development. It provides means for ensuring reproducibility of models and their assessment and coherent and transparent theory building (Guest and Martin 2020; Hale et al., 2020). The constraining inference process often used in Health Psychology (i.e., theorising about the mechanism of behaviour change) through use of formal modelling carried out in this chapter helps build models that can be identified, tested, and refuted. The present chapter specifies and implements computational models describing barriers and enablers of physical activity in HF. These models are identifiable, plausible, and falsifiable. Provided that the assumptions described in the models are valid, the present modelling study provides average estimated physical activity effects expected from future interventions developed on the basis of these models.

The assumptions underlying the proposed models of barriers and enablers predicting physical activity in HF were expressed in a model and computable format (West et al., Hale et al., 2020). This was done to disambiguate the assumptions of verbally described models offered in Chapter 6. The use of natural language introduces ambiguity (Oberauer and Lewandowsky, 2019), which may limit model comparison, testing and development. In order to ensure the testability of the offered models, in the present Chapter, the models were described formally following recent recommendations (Hale et al., 2020; Borsboom et al., 2020; Forstmann et al., 2011; Guest & Martin, 2020; Haslbeck et al., 2019; van Rooij & Baggio, 2020). Overall, the herein presented models satisfy the following criteria for rigorous modelling (Popper, 1963; Rothman et al., 2008): plausibility, internal consistency, parsimony (i.e. stripped of arbitrary elements), explanatory power (i.e. capturing as much variance as possible), falsifiability (i.e. predictions detailed enough to be disconfirmed by empirical evidence).

Another outcome of the present study was a new scale, BEPA-HF, designed to assess beliefs about physical activity specific to HF. The scale's content was developed following guidelines suggesting attention to relevance, refinement, comprehensiveness, and readability (COSMIN; Mokkink et al., 2006).

In most applications of Bayesian modelling researchers have more confidence in their data than in their prior (Gelman 2003). The present study is in the admittedly odd situation where this researcher has more confidence in her prior than in her data. The reason for this is that the prior was constructed from the results of two meta-analyses (Chapter 5 and Zhang et al. 2019) as well as the British National HF Audit (2018). The dataset, on the other hand, is extremely small (N=3) and non-representative of the HF population (mean age = 60).

7.7.2 Alternative models

An alternative explanation for what drives physical activity in HF can be provided by the Common-Sense Model (CSM, Leventhal et al., 1980; Leventhal, Phillips, & Burns, 2016), described in Chapter 6. In particular, physical activity in HF can be conceptualised as a self-management behaviour (WHO, 2003), clinically prescribed lifestyle change, and behaviour that either induces or helps manage a health threat (as described in Leventhal et al., 2016). As has been described in Chapter 6, illness belief, such as identification of breathlessness as the core symptom of HF which may lead to hypervigilance to getting out of breath upon exertion, strongly influences physical activity in HF according to the findings of the qualitative study. In the present study, this belief has been assessed using the illness identity subscale of the IPQ-R (Moss-Morris et al., 2002). However, given the extremely small sample size, it was not possible to assess whether the dichotomous variable ('this symptom is related to my heart failure') differentiated the levels of physical activity in HF in this study. People's beliefs about their illness influence the willingness to initiate and maintain behaviours that improve or maintain their health (Hagger and Orbell, 2003). Illness beliefs are also associated with physical and social functioning, coping, treatment adherence and a range of self-management behaviours (Fortune, Richards, Main, & Griffiths, 2000; Hagger & Orbell, 2003; Heijmans, 1998; Horne & Weinman, 2002; Leventhal et al., 1992; Meyer et al., 1985). However, a meta-analysis of prospective studies found only weak predictive association between illness beliefs and self-management behaviours (Aujla et al., 2016). Authors concluded that, while illness beliefs might contribute to better or worse self-management behaviours in chronic illness, they are not the only causal factor.

Another alternative to the HAPA model that might explain physical activity in HF in the context of self-management in chronic illness is Necessity and Concerns Framework (Horne & Weinman 1999; Horne et al., 2013; Wei et al., 2017). From this perspective, the nonadherence to a self-management behaviour (i.e., physical activity in HF) is partially attributed to limiting practicalities, such as complex regimen or burden associated with engaging in the prescribed behaviour, and partially motivated by a set of beliefs, which fall into two categories: Necessity beliefs – perceived personal need for treatment or recommended lifestyle change; and Concerns – perceived and anticipated potential adverse consequences. The Necessity and Concerns Framework predicts that adherence is associated with stronger perceptions of Necessity for treatment and fewer Concerns about adverse consequences.

7.7.3 Study limitations

The present study does not describe causal relationships explicated by the models. It is recommended to assess these using *N*-of-1 design and intensive assessment over a period of time. Once the causal power of the model is supported it then can inform the development of a behaviour change intervention, the mechanism of which would closely follow the presented graphs. Then, a randomised-controlled trial evaluating these interventions could assess the causal relationship. Using methods developed by Barr et al. (2018) based on Pearl (2009), the present study provides only estimates of potential effects on physical activity in HF if HAPA, an Auxiliary model, or MB-MF were first indeed supported by a large study to be relevant, and then applied to inform a behaviour change intervention to increase physical activity n HF.

In line with studies evaluating HAPA (Barg et al., 2012; Paxton, 2016; Pinidiyapathirage, Jayasuriya, Cheung, & Schwarzer, 2018 (Mohammadi Zeidi et al. 2020), in this study, there is a trend (*N*=3) suggesting physical activity increases as a function of both Action Self-efficacy and Volitional Self-efficacy. Greater Intention and Action Planning, on the other hand, was negatively associated with physical activity as indicated by the data accelerometry data. This would contradict the predictions made by HAPA. However, more data is needed to draw any conclusion on the relevance of these constructs.

The auxiliary hypothesis (H1) that Behavioural goal will predict physical activity in HF using objective measurement (triaxial accelerometer) to a greater extent than Intention was the preferred model for explaining the dataset (*N*=3) using Bayesian Hypothesis testing. It is also suggested that the model derived from the qualitative study (Chapter 6) predicts physical activity levels better than a null hypothesis (not auxiliary) as well as HAPA (H3 is supported). The MB-MF-Pavlovian, also is a very likely model that can explain physical activity in HF. The model-free (physiological state: dyspnoea), and model-based (health event and auxiliary model-consistent beliefs) predicted physical activity in HF to a greater extent than the model-free model (physiological state: dyspnoea), and model-based (health event and HAPA-consistent beliefs) (H4 is supported).

This dataset (*N*=3) shows a trend suggesting that MVPA (mins/days) is considerably smaller when the Risk Perception (i.e. concerns) about the behaviour are high. This indicates that indeed individuals living with HF may not engage in physical activity when they are concerned about potential negative outcomes of the behaviour.

Not being in a state of Functional Independence was not predictive of higher (than average) levels of physical activity. It was assumed from the qualitative findings, that individuals living with HF would engage in physical activity in order to gain Functional Independence (Goal (Outcome)). The lack of functional independence was indeed correlated with lower levels of physical activity, while it does not necessarily drive the goal-directed behaviour in the pursuit of Functional Independence. In future studies, it is important to assess outcome goals that are personally relevant. The outcome goal was assessed using the newly developed BEPA-HF scale. A validated assessment of the outcome goal is needed to draw conclusions regarding the association between the goal outcome attainment and the levels of physical activity in HF. Together with the lack of goal-directed behaviour supported by the preliminary findings, indicates that model-free processes are the predominant predictors of physical activity in HF.

Even if a sufficiently powered study was available it still would have the following limitations. The effects predicted by HAPA, MB-MF-Pavlovian, and the auxiliary models were simulated via a widely used method (Pearl et al., 2009; e.g. West et al., 2019 and Hale et al., 2019). However, only a few known contextual factors were included as exogenous variables across the models. These are age, comorbidity, social support and implantable devices. Upon obtaining new evidence suggesting other contextual determinants, these should be specified as the exogenous variables across *DAGs*. In addition, the relationships between social support, comorbidity and implantable device and self-efficacy were specified using sparse data.

The systematic review and meta-analysis conducted as part of this research as well as previous experimental research on the effect of accelerometers without behavioural feedback (Bravata et al., 2007) found that monitoring behaviour even without providing feedback promoted physical activity. Therefore, use of accelerometers may increase the levels of physical activity that would otherwise be performed in natural settings when participants are not being monitored. Therefore, it is likely that the levels of physical activity for the present sample are overestimated and not representative of the general HF population.

7.7.4 Future research recommendations

Further model development is required. It is unclear from the data whether the model-free/habitual processes can be inferred from breathlessness alone. It is therefore recommended to assess habit using self-reported habit index (automaticity, frequency, and relevance to self-identity; Rebar et al., 2018). This was not done in this study because the choice of the measurements was informed by the elicited beliefs from qualitative studies. The qualitative study did not provide evidence that these were as relevant to the behaviour in HF. Physical activity in HF is largely a deliberative behaviour which requires weighing up the advantages and associated risks (i.e. model-based). While breathlessness acts to inhibit the formation of habit and automaticity with which an individual engages in physical activity. Further research is required to investigate the relationships between habit, breathlessness, and physical activity in HF (for example, how long after the first diagnosis (or prior) an active individual is likely to break the habit; what preventative factors exist). In addition, the power analysis recommends considerably larger samples to establish statistical significance for the models. These results can be used in informing the design of a future study.

7.8 Conclusion

Given that the present feasibility study does not suggest that a sufficiently large cross-sectional study is feasible, alternative research designs should be used (e.g., *N*-of-1).

The present chapter makes sample size recommendations, supplements with a scale of good content validity and offers several formalised models that can be tested. The model developed in this thesis was based on beliefs elicited from people with HF. It builds on, and contextualises for HF, an established behaviour change theory: Health Action Process Approach (HAPA; Schwarzer 2008). It was formally described as recommended by Guest and Martin (2020) and van Rooij et al. (2020). The computational model summarises our current understanding of barriers and enablers to physical activity in HF as informed by systematic reviews and semi-structured interviews with people living with HF. This model is a plausible, internally consistent account and is specified in enough detail for future studies to falsify it or amend it.

8 Discussion

Physical activity is recommended to individuals living with HF (NICE, 2018). However, they engage in physical activity considerably less than the general population (O'Donnell et al., 2020). Physical activity promotion is particularly challenging in the context of HF, owing to the complexity underlying physical activity behaviour (Craig et al., 2008) and the many challenges this population group faces in the enactment of the behaviour.

The overall aim of this thesis was to extend understanding of how to promote physical activity among people with HF. The series of research studies carried out here adhered to the MRC guidance for developing complex interventions, focusing on the development phase (Craig et al., 2008). This chapter first outlines the contributions and limitations of each study. Next, it offers considerations for intervention development. Finally, recommendations for future research are made. The key contributions of this thesis are outlined for each chapter in Table 8.1.

This thesis integrated several different forms of evidence and analysis. The first study evaluated the evidence base in a meta-analysis of RCTs evaluating interventions. The second study was a Bayesian synthesis of qualitative and quantitative evidence regarding factors that influence the behaviour. The third study included semi-structured interviews with the target group (adults age>70 living with HF), findings of which then were modelled and evaluated in a small feasibility study (*N*=3). The present chapter integrates the findings of all these in a way that can inform the design of a large confirmatory study and subsequent development of new interventions.

8.1 Evidence base

The evidence-base was evaluated to identify what physical activity interventions work for which subgroups of the HF population, in what settings, and delivered in what way. The results were reported in a systematic review and meta-analysis (Chapter 4 and updated search in Appendix A). The research questions were: **1.** ***Are the current interventions effective in promoting physical activity in HF?*** **2.** ***What intervention characteristics are associated with efficacy in increasing physical activity in HF?***

Table 8.1. Key contributions of the present thesis

Chapter	Key contributions
Evaluating evidence base (MRC guidance, Craig et al., 2008):	
Chapter 4: ***Meta-analysis of RCTs evaluating physical activity interventions***	1. Identified a potentially effective intervention approach for younger adults (<70 years old): *Exercise and Behaviour Change* interventions that include the BCTs outlined in Table 8.2. 2. Identified the target group most in need of a new physical activity intervention: *older adults living with HF (>70 years old).*
Identifying/developing Appropriate theory (MRC guidance, Craig et al., 2008):	
Chapter 5: ***Bayesian synthesis of qualitative and quantitative evidence regarding factors that influence physical activity in HF***	3. Synthesised evidence on the comparative influence of a set of clinical, demographic and psychosocial factors on physical activity in HF. 4. Identified the contextual factors influencing physical activity in HF: *age*, *comorbidity,* and *depression.*
Chapter 6: ***Semi-structured interviews study with older adults living with HF***	5. Formulated a total of 78 belief statements describing barriers and enablers to physical activity that older adults (>70) with HF face. 6. Identified the following key relevant barriers and enablers to physical activity enactment in HF: *Environmental Context and Resources*, *Goals*, *Social Influences*, *Beliefs about Consequences*, *Beliefs about Capabilities*, *Behavioural Regulation,* and *Breathlessness*.
Chapter 7: ***Modelling barriers and enablers to physical activity in HF***	7. Specified and compared formal computational models of barriers and enablers to physical activity: 8. Contextualised Health Action Process Approach and MB-MF-Pavlovian model to HF. 9. Developed a scale of barriers and enablers to physical activity with good content validity. 10. Conducted a power analysis to inform the design of future quantitative studies.

8.2 Intervention characteristics associated with efficacy

Home- and centre-based forms of cardiac rehabilitation are equally effective in improving clinical outcomes – reducing mortality, improving cardiac capacity and health-related QoL – in patients after myocardial infarction or revascularisation, or with HF (Anderson et al., 2017). The results of the presented meta-analysis indicate that home and centre-based settings may differ in the achieved improvement in physical activity outcome. Centre-based interventions delivered in groups and facilitated by a physiotherapist produced significant effects, whereas, those delivered at home did not (Appendix A). The difference in the impact of intervention settings on clinical and behavioural outcomes should be explored in future RCTs.

Exercise and Behaviour Change approach is suggested to be efficacious in increasing physical activity in HF above *Exercise* alone. This highlights the importance of a supplementary theory-based intervention. The presence of the following strategies (Table 8.2) in addition to an exercise programme were found efficacious: (1) prompts and cues to engage in physical activity, (2) explicit, detailed and salient advice from a health professional, (3) enhancement of the everyday environment with exercise equipment, (4) performance of physical activity in different contexts, (5) monitoring by health professional and (6) self-monitoring of the performed physical activity, (7) gradual increase of amount and intensity of physical activity, (8) exercise training, and (9) detailed planning (when, where, how much and at what intensity physical activity will be performed), as well as (10) goal-setting were identified as promising in promoting physical activity.

The efficacy of these strategies alludes to the relevance of the behaviour change mechanisms outlined in Table 8.2. Basing on the recommendations made by an expert consensus (Connell et al., 2018), it is concluded from the meta-analysis (Chapter 4) that the following intervention mechanisms should be further explored on their relevance to promoting physical activity in HF: Cuing, Attitude toward the behaviour (ATB), Environment, Beliefs about Capabilities, Feedback, Behavioural regulation, feedback and goal. In addition, these findings allude to the relevance of nudging through the modification of the environment (Thaler & Sunstein, 2008); positive beliefs about consequences of physical activity validated and reinforced by a health professional (Godin, Bélanger-Gravel, Eccles, & Grimshaw, 2008); habit formation through repetition of physical activity in different contexts (Gardner, 2018); and self-regulatory processes (9; 10) (Gollwitzer & Sheeran, 2006). The relevance of these proposed mechanisms needs to be supported by suitably designed RCTs before making any conclusions. Upon such confirmation of this evidence, the strategies should be considered in terms of APPEASE criteria: affordability, practicality, effectiveness within the real-world settings, acceptability, safety, and equity.

8.2.1 Behaviour change theory implementation

The research focus on the determinants of exercise was encouraged by Conraads and colleagues in the position statement on exercise training in HF (Conraads et al., 2012). Subsequently interest in developing physical activity interventions for HF has grown over the past eight years. Previously, identified trials evaluating exercise-based interventions (n =139) did not consider behavioural outcomes in HF or behaviour change. Recently the following trials took place: REACH-HF trial (Dalal et al., 2018), HEART Camp trial (Pozehl et al., 2018), HF-ACTION trial (O'Connor et al., 2009), and trials evaluating a Disease management programme (Smeulders et al., 2009) and Cognitive Behavioural Therapy (Freedland, Carney, Rich, Steinmeyer, & Rubin, 2015). These trials considered the determinants of physical activity, and behaviour change theory (TCS score varied between 5-7). The efficacy identified by these trials varied substantially (*SMD* varied between -0.11 to 3.21). CBT was not suggested to be efficacious in increasing physical activity (Freedland et al., 2015). The implementation of a combination of Self-determination Theory, Control Theory and the Common-sense model produced a non-significant effect (Dalal et al., 2018), Social Cognitive Theory (SCT) produced medium effect (Pozehl et al., 2018); a combination of SCT and Transtheoretical Model of Change (TTMC) (O'Connor et al., 2009) produced large effect.

Table 8.2. Behaviour change techniques, suggested to be promising in increasing physical activity in HF by the meta-analysis, and the corresponding mechanism of action, theory, TDF domain and COM-B component.

BCT identified to be associated with efficacy by the meta-analysis (Chapter 4)	Mechanism of action (Connell et al., 2018)	Linked theory (Bohlen et al., 2018)	TDF domain	COM-B
Prompts/cues	Cuing	-	*Environmental Context and Resources*	Physical Environment
Credible source	Attitudes toward the behaviour	-		Social Environment
Adding objects to the environment	Environment, Cuing	-	*Environmental Context and Resources*	Physical Environment
Generalisation of the target behaviour	Beliefs about Capabilities	-	*Beliefs about Capabilities*	Physical Capability
Monitoring of behaviour by others without feedback	Cuing	-	-	-
Self-monitoring of outcomes of behaviour	Feedback	Health Action Process Approach	-	-
Graded tasks	Beliefs about Capabilities	Health Action Process Approach	*Beliefs about Capabilities*	Physical Capability
Behavioural practice/rehearsal	Skills Behavioural regulation	Social Cognitive Theory	*Beliefs about Capabilities*	Physical Capability
Action planning	Goals	Health Action Process Approach	*Behavioural Regulation*	Psychological Capability
Goal setting (behaviour)	Goals	Health Action Process Approach	*Goals*	Reflective Motivation

1.1.1 Intervention target group

The evidence suggesting efficacious approaches was drawn from RCTs with considerably younger samples (age 60) than the general HF population (age 80). No intervention applied to the older subgroup was efficacious (Witham et al., 2005, van der Wal 2006, Dalal et al., 2018). Therefore, it is not known how to increase physical activity in older adults (>70 years old), who constitute the majority of these clinical populations.

The clinical profiles of older adults differ from younger adults, including a significantly worse prognosis and a larger number of comorbidities (Butrous & Hummel, 2016). Older adults may also differ in their beliefs about physical activity and experience barriers and enablers qualitatively different to those experienced by the younger population (French, Olander, Chisholm, & McSharry, 2014). Too little is known about how to promote physical activity in HF for this age group. In order to tailor physical activity intervention to the needs of older adults living with HF, it is first necessary to understand the barriers and enablers experienced by this target group.

1.1.2 Major limitations[14] of the meta-analysis of physical activity interventions

Many intervention characteristics were present in clusters. For example, action planning, goal (setting), graded tasks and *Exercise and Behaviour Change* approach were often present simultaneously. Thus, it is not possible to conclude whether each of the proposed characteristics are efficacious on their own or in combination. They should be evaluated in RCTs, preferably in a multi-arm trial comparing their effects. However, such investigation may be very time consuming and burdening on people with HF.

HF-ACTION trial (O'Connor, 2009) made up the majority of the meta-analysis sample but is unrepresentative of the HF population. The intervention it tested was resource-

[14] The full list of limitations is reported in Chapter 4.

intensive and was delivered to younger adults (56 years old). Therefore, it jeopardised the ecological validity of the meta-analysis findings.

When HF-ACTION is excluded in a sensitivity analysis, only a small non-significant effect of Exercise & Behaviour Change approach is observed. While the following characteristics are identified as efficacious in older adults living with HF: Remote Communication and Feedback approach that includes strategies such as Biological feedback (e.g. symptom monitoring and feedback) delivered by a nurse using telehealth devise (mode), as well as self-monitoring of the behaviour, and Information about health consequences (Bernocchi et al. 2018; Boyne et al. 2014). The detailed findings are reported in Appendix A. Therefore, more trials evaluating Exercise and Behaviour Change and Remote Monitoring and Feedback approaches for their efficacy in promoting physical activity in HF are needed. The second half of the thesis delineated psychological theory that may inform the development of an intervention.

1.2 Appropriate theory

As has been outlined in Chapter 3, theory relevance and potential applicability depends on the context where it is being applied. To achieve meaningful change in a target behaviour, first the contextual as well as the modifiable determinants of the behaviour should be identified. This principle is shared by most established frameworks for developing interventions (Araújo-Soares et al., 2019; Craig et al., 2008; Hankonen & Hardeman, 2020; Kok et al., 2016; S Michie et al., 2014; O'Cathain, Croot, Sworn, et al., 2019).

1.2.1 Contextual factors influencing physical activity in HF

First a systematic literature review of observational studies was performed to identify correlates of physical activity. The research question was: ***What are the barriers and enablers to physical activity in HF?***

An evaluation of reported determinants was situated in this context of low physical activity characteristic for HF (Chapter 5). The contextual factors identified by this Bayesian meta-analysis are depression, comorbidity, and age. Depression reduced the probability of physical activity enactment by a factor of four, and age and comorbidity by over twofold. These contextual factors need to be carefully considered in designing an intervention and in a randomised-controlled trial evaluating this intervention.

1.2.2 Major limitations[15] of the Bayesian synthesis of qualitative and quantitative research

The systematic review is subject to the following study-level limitations. The observational studies included in the review did not always control for confounding effects when assessing correlates of physical activity. Two studies were exposed to high selective reporting bias. As such only significant barriers and enablers were reported.

Bayesian synthesis integrates qualitative and quantitative evidence by first representing qualitative evidence as a prior belief distribution, and then updating this distribution with quantitative evidence to produce a new belief distribution incorporating both kinds of evidence. Therefore, one set of limitations stem from the way the prior was elicited. This was done using an expert elicitation task. While this is an established technique for formalising an informative prior, it is by definition subjective, and thus depends strongly on the members of the expert panel (Albert et al., 2012; Choy et al., 2009). In this case, the panel was too limited, containing only health psychologists. It would benefit from including other stakeholders such as HF nurses or cardiologists. As for the quantitative findings, the relationships between these variables ought to be multivariate; they were summarised using pairwise meta-analysis of univariate relationships between each identified factor and the levels of physical activity in HF. However, only a small number of studies provided information about the same set of multivariate variables.

[15] The full list of limitations is reported in Chapter 5.

1.2.3 Modifiable factors influencing physical activity in HF

To bring about change in behaviour, an intervention should target modifiable determinants (Michie et al., 2011). A Bayesian meta-analysis identified a lack of evidence regarding modifiable barriers and enablers of physical activity in HF. Negative attitude (*Emotion/Optimism*) was the only modifiable factor identified by the systematic review. However, it was not clear how exactly negative attitude results in low levels of physical activity in HF. The evidence on other modifiable factors was uncertain.

Qualitative studies are recommended in identifying the needs, enablers and barriers of the target group (McDonalds et al., 2017; Rodrigues et al, 2017; Yardley et al., 2017). Understanding of the modifiable determinants of physical activity in HF in older adults is limited (Chapter 5). This gap in knowledge was addressed by the qualitative study (Chapter 6). The primary goal of the qualitative semi-structured interview study was to elicit a better understanding of barriers and enablers to physical activity. The qualitative study using TDF-based interviews formulated 78 belief statements describing the barriers and enablers. The belief statements were mapped onto constructs and domains specified by TDF (Cane et al., 2012). Constructs and domains containing beliefs that were both pervasive and common were deemed most relevant. The modifiable factors included: risk perceptions/concerns about physical activity (*Beliefs about Consequences*), self-efficacy defined by age, comorbidities, and heart condition (*Beliefs about Capabilities*), social support (*Social Influences*; barrier and enabler), major event (*Environmental Context and Resources*), goal behavioural (*Goal)*, action planning *(Behavioural Regulation).*

On the basis of the findings of the qualitative study, tentative suggestions of potentially promising BCTs in increasing physical activity, are made (Table 8.3). However, these are subject to satisfactory confirmation of the relevance of these domains in an RCT evaluating efficacy of the corresponding strategies.

Table 8.3 Proposed behaviour change techniques (BCTs) to be included in future experimental evaluation on the basis of the findings of the systematic literature review (Chapter 5) and semi-structured interview studies (Chapter 6).

TDF domain suggested by the findings of the systematic review	TDF domain suggested by the findings of the semi-structured interview study	Proposed behaviour change techniques (Michie et al., 2013, BCT v1.)	COM-B	Necessity and Concerns Framework	Conditioning
Environmental Context and Resources	*Environmental Context and Resources*	**Adding objects to the environment**, **Prompts/cues**, Avoidance/changing exposure to cues for the behaviour	Physical Opportunity	-	-
-	*Goals*	**Goal setting (behaviour),** Goal setting (outcome), Discrepancy between current behaviour and goal	Reflective Motivation	-	-
Social Influences	*Social Influences*	Social support (unspecified), Social support (emotional), (Social support practical)	Opportunity	-	-
Beliefs about Consequences	*Beliefs about Consequences*	Information about consequences, Salience of consequences, Feedback on behaviour, Feedback on the outcome of behaviour, Pros and cons, Emotional consequences, Covert sensitisation, Anticipated regret, Comparative imagining of future outcomes, Vicarious reinforcement	Reflective Motivation	**Necessity**	-
Beliefs about Capabilities	*Beliefs about Capabilities*	**Behavioural practice and Rehearsal**, **Graded tasks,** Social comparison, Focus on past success, Verbal persuasion about capability	Psychological Capability	-	-
Behavioural Regulation	*Behavioural Regulation*	**Action planning**, Self-monitoring behaviour, Problem solving, Goal setting outcome, Self-monitoring , Feedback on behaviour, Habit formation	Psychological Capability	-	-
Emotion/Optimism	-	Reduce negative emotions, Information about health consequences, Information about emotional consequences	Automatic Motivation	-	-
-	*Breathlessness*	Body changes, Information about health consequences, Remove Punishment, **Behavioural practice and Rehearsal,** Exposure, **Graded tasks,** Biofeedback	Physical Capability Automatic Motivation	Concerns about engaging in physical activity (i.e. physical activity brings on breathlessness	Pavlovian learning

Note: BCTs in bold are supported by the meta-analysis of the RCTs as promising in increasing physical activity in HF (Chapter 4).

The author of the thesis assessed each transcript on the presence of lexical patterns used in natural language, to infer causality (Doan et al., 2019). These formed the basis for the causal representations of perceived barriers and enablers. The qualitative findings suggested the relevance of the following models: the model-based and model-free Pavlovian (Dayan & Berridge 2014; Zhang et al., 2009), Health Action Process Approach (Schwarzer, 2008), and an auxiliary model. The auxiliary model was distinguished from HAPA by the lack of the relevance of intention and outcome expectancies and potential relevance of major-health event and goal (behavioural) to the physical activity in the context of HF.

All frameworks for developing behaviour change interventions emphasise detailing a hypothesized mechanism. This can be done by detailing causal models (Aruijo-Soares, 2018), logic models, programme theory (Hardeman 2020), or mechanism of action (Michie et al., 2018). Guest and Martin (2020) and Van Rooij et al. (2020) advise formally describing these, not only for evaluation of interventions in RCT, but also for hypothesis testing in cross-sectional studies. Such models should draw on existing theories and evidence, as well as views of stakeholders (Craig et al., 2008). Once a model is formally described, it can then be assessed in a quantitative study (e.g., *N*-of-1 design), and then for efficacy in a randomised-controlled trial. In this thesis, models developed on the basis of the qualitative findings and informed by psychological theory. Following methods developed by Pearl (2009), the models were specified as directed acyclic graphs (*DAG*) and structural equation models, and effects that are ought to be achieved by interventions informed by these models were estimated. Then they were contrasted against one another on the basis of a small cross-sectional dataset (*N*=3) using Bayesian hypothesis testing. A scale with good content validity was developed and power analysis was performed to inform the design of future confirmatory quantitative study. Given the lack of supported feasibility of a large, scaled study, it is recommended to explore other options (e.g., *N*-of-1 design).

1.2.4 Major limitations of the empirical studies concerning the development of the model of barriers and enablers to physical activity in HF

Creswell and Miller (2000) recommend engaging in reflexivity while conducting a study to be mindful of the assumptions that may have contributed to the findings. The author of the thesis engaged in debriefing and reflection throughout the conduct of the study. It is also recommended to base the analysis on rich and thick data and to engage peers in informing the research design (Creswell & Miller, 2000). Therefore, rich and thick transcripts (mean duration = 40 mins, *SD*=20) were analysed. These were obtained using a TDF-based interview schedule on which the author of the thesis sought feedback from experts. Reflexivity was ensured through the use of journals. However, comments on the findings have not been yet provided by the participants of the study. Therefore, the credibility of the study might benefit from seeking their feedback. Finally, The lexico-syntactic patterns identified across the transcripts may have resulted in the omission of implicit causal links among perceived barriers and enablers.

The developed scale should be further assessed for its validity and reliability in a quantitative study. The findings of Bayesian hypothesis testing should be interpreted with extreme caution due to the extremely small sample size (*N*=3). The conclusions of the computational modelling are limited by contextual factors. Upon obtaining new evidence suggesting other contextual determinants, these should be specified as the exogenous variables across *DAGs*.

The extremely small sample size (*N*=3) may suggest conducting a large cross-sectional study is not feasible. Only seven people expressed their interest to the clinical team, indicating potential difficulties in recruiting this population group[16]. The power analysis indicated a much larger sample size is needed for a study assessing these models.

[16] The COVID-19 pandemic impeded further recruitment.

1.3 Recommendations for future research

It is recommended to consider a nested mixed-methods study or parallel mixed-methods study as an alternative to the herein carried out sequential study if the available time or resources are limited. It has been previously documented that TDF-based sequential studies are lengthy (Atkins et al., 2017). It is also recommended to quantitatively assess the models proposed in this thesis using N-of-1 design because a large cross-sectional study may not be feasible in this hard to reach population (older adults (>70 years old) living with HF.

Further research that will enrich the development of a physical activity intervention for HF might constitute a study with health professionals and the partners or carers of the individuals living with HF. This might extend our understanding of how to implement the intervention in the existing clinical context and how best to encourage physical activity using emotional and instrumental social support (Social Influences) that was found to be relevant to the behaviour.

Additionally, other factors that are likely to contribute to the effectiveness of the future intervention in the real-world settings like acceptability of behaviour change interventions and fidelity with which they are delivered should be considered. Acceptability is defined as the extent to which interventions are considered appropriate by those delivering and those receiving the interventions based on the former and anticipated cognitive and affective responses to it (Sekhon, Cartwright, & Francis, 2017). This should be considered when developing, evaluating and implementing a physical activity intervention for people living with HF. Since personal accounts of those living with HF took centre-stage throughout this research programme (i.e., semi-structured interviews and public-patient-involvement) it is expected the acceptability of future interventions will be improved if they are developed having these findings in mind. However, substantially more research will be required evaluating the acceptability of the intervention once it is developed making use of existing frameworks (e.g., Theoretical Framework of Acceptability (v2), Sekhon et al., 2017).

Intervention fidelity is defined the reliability (i.e., the consistency) and validity (i.e., the appropriateness) with which the intervention is delivered, i.e., the extent to which the intervention was delivered as planned (Bellg et al., 2004; Carroll et al., 2007; Toomey et al., 2020). While, currently there are no standardised methods of fidelity assessment (Toomey et al., 2020), a detailed checklist of core intervention components can be designed prior evaluation of an intervention and intervention delivery can be audio and video recorded, enabling fidelity assessment (e.g., (Bearne et al., 2019)).

A study comparing an auxiliary model to HAPA might require a sample size between 172 and 409 people. Given the observed recruitment difficulties, an appropriate time and number of sites should be allocated, ideally not during a pandemic.

Depression is a common comorbidity in older adults with HF, and a large barrier to physical activity and attainment of its contingent health benefits. It is recommended to further investigate how to improve physical activity in depressed individuals with HF. Therefore, this group should be purposefully recruited into future semi-structured interview studies.

The following barriers and enablers that were identified only by the qualitative study should be further confirmed in a large cross-sectional study: *Goals* and *Breathlessness*. The following barriers and enablers as well as the strategies that may address them are supported by convergent evidence from the meta-analysis of RCTs, the Bayesian synthesis and the qualitative study (Table 8.1; 8.2): *Environmental Context and Resources*, *Belief about Capabilities*, and *Behavioural Regulation*.

1.4 Conclusion

In summary, the systematic review of RCTs evaluating intervention made suggestions on potentially useful intervention characteristics. The meta-analysis of observational studies defined contextual determinants of physical activity in HF. Both reviews highlighted the importance of assessing the needs of older adult living with HF (>70 years old). The semi-structured interview study identified relevant modifiable determinants such as *Goals, Beliefs about Consequences*, *Beliefs about Capabilities*, *Social Influences*, and *Behavioural Regulation*. Computational modelling helped in assessing plausibility and providing grounds for model comparison. These are all essential for modelling behaviour in a way that can inform a behaviour change intervention.

Appendix A. Meta-analysis including the results of the updated search (January 2020).

Efficacy of interventions to increase physical activity for people with heart failure: a meta-analysis with the updated search

As was outlined in Chapter 4, the meta-analysis search was updated in January 2020. The Risk of Bias evaluation was updated. In addition, a Risk of Bias 2 (Sterne et al., 2019) was used instead of Risk of Bias (Higgins et al., 2017).

Data extraction and risk of bias assessment

The relevant information was extracted from trial reports (article, supplementary materials, and protocols) using a standardised Cochrane data extraction form (Higgins & Green, 2017). The Cochrane Collaboration Risk of Bias tool (2) was used to assess the methodological quality of the included trials.

Data coding

The interventions were classified in terms of the general approach to physical activity promotion (e.g. exercise), setting (e.g. home vs centre), mode of delivery (e.g. group vs individual), facilitator (e.g. nurse). The Theory Coding Scheme (TCS) (Susan Michie & Prestwich, 2010) was used to describe the extent to which trials employed a behaviour change theory in designing the interventions, The TCS score ranges from 0 (no theory) to 8 (most extensive theory use). The intervention and comparator treatment were described in terms of the included behaviour change techniques. The interventions were independently coded by two reviewers (69.20%) using The Behaviour Change Techniques Taxonomy (BCTTv1) (Susan Michie et al., 2013) – a standardised method for describing intervention content. Disagreements were resolved through discussion. The consensus scheme was used by AA to code the remaining interventions.

Statistical analysis

Main effect

Meta-analysis was performed using the `metafor` library in `R` (Viechtbauer, 2010). Meta-analysis using a random effect model was performed to estimate the overall efficacy of interventions using restricted maximum likelihood. The standardised mean difference (SMD) in physical activity levels between the main intervention and a control group was chosen as the estimate of the efficacy to mitigate the heterogeneity in the outcome assessment. A Q-statistic was used to assess the presence of between-study heterogeneity. Heterogeneity index (Isq) is reported as the total unexplained variability in effect. and are reported as the dispersion and standard deviation of the true underlying effect, respectively. Efficacy at intervention completion, 3-month, 6-month (short-term), and 12-month (long-term) follow-up was evaluated.

Exploratory meta-analysis

To explore the heterogeneity of the interventions, using recommended methods (Borenstein et al., 2009) the moderation of the efficacy by general approach (e.g. exercise programme), setting, mode of delivery (e.g. home-based), facilitator (e.g. nurse), behaviour change strategies (e.g. goal setting), and participant characteristics (i.e. mean age, NYHA class, proportion of males, mean EF (%), Aeschimic Aetiology (%)) were specified as predictors in the random-effect model. Per recommendation by Debray et al. (Debray et al., 2017), the Knapp and Hartung adjustment was applied to account for the uncertainty in the estimated between-study variance resultant from the small number of trials.

Results

Results of the search

The search results and reasons for exclusion are listed in the PRISMA diagram (Figure 1). A total of 20 trials evaluating 22 interventions post-completion (n = 21, (Ajiboye, Anigbogu, Ajuluchukwu, & Jaja, 2015; Bernocchi et al., 2018; Boyne et al., 2014; Brodie & Inoue, 2005; Collins et al., 2004; Corvera-Tindel, Doering, Woo, Khan, & Dracup, 2004; Cowie et al., 2011; Dalal et al., 2018; Freedland et al., 2015; Jolly et al., 2009; O'Connor et al., 2009; Pozehl et al., 2018; Smeulders et al., 2009; Tomita et al., 2008; van den Berg-Emons et al., 2004; Willenheimer et al., 1998; Witham et al., 2005; Yeh et al., 2011; Young, Hertzog, & Barnason, 2016)), at 6-months (n = 5, (Meng et al., 2016; Smeulders et al., 2009; Willenheimer et al., 1998; Witham et al., 2005; Young et al., 2016)), and 12-months (n=5, (Dalal et al., 2018; Freedland et al., 2015; Jolly et al., 2009; Meng et al., 2016; O'Connor et al., 2009; Smeulders et al., 2009)) follow-up were included in the meta-analysis.

PRISMA 2009 Flow Diagram

Identification

Records identified through database searching
(n = 6091)

Additional records identified through other sources (Web of Science (n = 19), Be Part of research (n = 40), Clinicaltrials.gov (434)

Records after duplicates removed
(n = 5097)

Screening

Records screened
(n = 5097)

Records excluded
(n = 4816)

Eligibility

Full-text articles assessed for eligibility
(n = 281)

Full-text articles excluded, with reasons (n = 261):

No physical activity outcome assessment (n = 139)*

Wrong publication type (n = 40)

Not HF (n = 16)

Not a behavioral intervention (n = 30)

A registered trial (n= 21)

Reported in a non-English language (n = 9)

Pilot studies (n = 5)

Risk of bias (n = 1; significant differences in pharmaceutical treatment between groups)

Studies included in meta-analyses
(n = 20)

Included

Studies included in post-intervention assessment: n = 19; follow-up: n =5.

*Authors were contacted with a request to share numerical results on physical activity outcome

Appendix A. The study flow chart (PRISMA 2009) .

The pilot studies of the included trials are: Barnason et al., 2003, Duncan 2003, Shoemaker (2018), Seo (2018), Hornikx (2019). These were excluded from the meta-analysis. In addition, a high risk of bias was identified in Koelling et al. (2009). The intervention group received a pharmaceutical treatment while the control group did not.

Study characteristics

The trials were conducted between 1999 and 2018. The median sample size was 100 . The trials included a total of 6277 participants. A large proportion (37%) of participants were drawn from the HF-ACTION trial (n=2331)(O'Connor et al., 2009).

Appendix A. Study and Participant Characteristics,

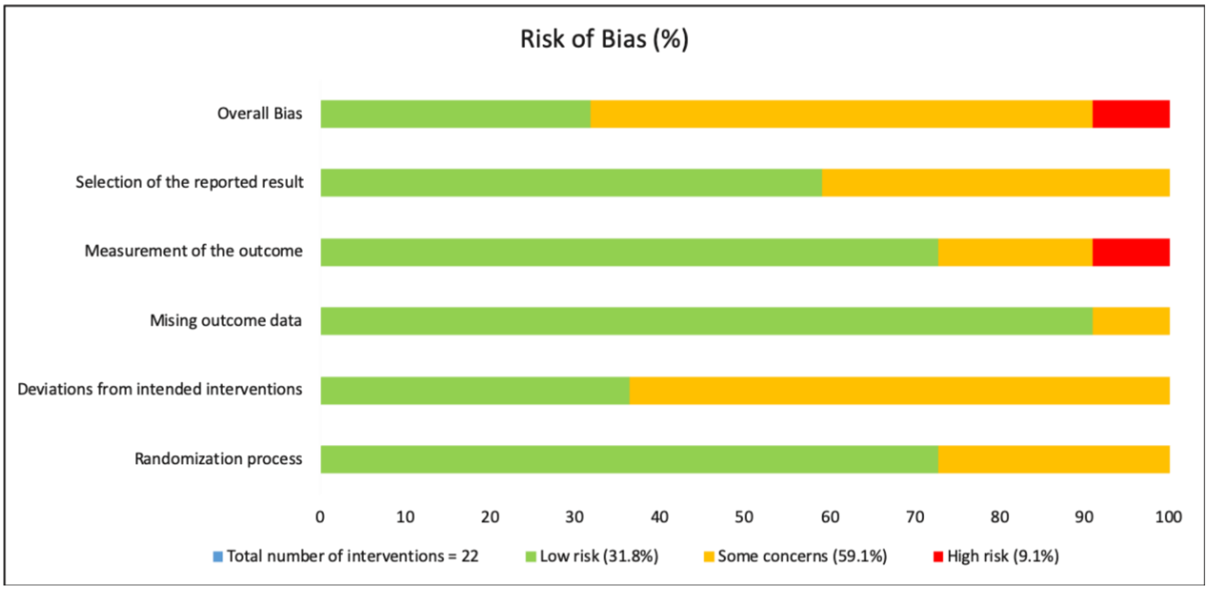
	Author, year	Country	Number of participants		Assessment time points		Mean age, years	Male, %	LVEF, %	NYHA II-III, %
			Control	*Intervention*	*Post-intervention (time from baseline)*	*Follow-up (time from intervention completion)*				
1.	Ajiboye et al., 2018	Nigeria	23	28	12 weeks	-	54	53.7	nr	nr
2.	Bernocchi et al., 2018	Italy	56	56	Four months	Two months	71(9)	88%	44.5	45
3.	Boyne et al., 2014	Netherlands	185	197	One year	-	71	58	<40	29; 21
4.	Brodie et al., 2005; 2008	UK	32	30 (MI and UC);30 (MI)	Eight weeks	-	79	Nr	30	28; 58
5.	Collins et al., 2004	UK	16	15	24 weeks	-	64	100	29	nr
6.	Corvera-Tindel et al., 2004a	USA	42	37	12 weeks	-	63	99	27	80; 20
7.	Cowie et al., 2013	UK	20	20 (Home); 20 (Hospital)	Eight weeks	-	66	85	<40	62; 38
8.	Dalal et al., 2018	UK	92	93	12 weeks	-	70	78	34	59
9.	Freedland et al., 2015	USA	60	58	Six months	12 months	56	53.8		42.4
10.	Jolly et al., 2009	UK	85	84	24 weeks	12 months	66	76	<40	75; 20
11.	Meng et al., 2013; 2016	Germany	227	248	nr	6; 12 months	61	75	31.7	54.7
12.	O'Connor et al., 2009	USA (88.72%) Canada (8.07%) France (3.33%)	1172	1159	24 weeks	12; 30 months	59	72	<35	62; 36
13.	Pozehl et al .,2018	USA	102	102	18 months	-	60	55.4	40.5	91.2
14.	Smeulders et al., 2009	Netherlands	131	186	Six weeks	6;12 months	67	73	<40	64; 36
15.	Tomita et al., 2008	USA	13	19	One year	-	76	32.5	nr	79; 21
16.	van den Berg-Emons et al., 2004	Netherlands	16	18	12 weeks	-	59	81	24	56; 44
17.	Willenheimer et al.,1998	Sweden	27	23	16 weeks	Six months	64	70	35	50; 36
18.	Witham et al., 2005	UK	41	41	12 weeks	Six months	80	63	nr	61; 39
19.	Yeh et al., 2004	USA	50	50	12 weeks	-	68	56	29	62; 18
20.	Young et al., 2015; 2016	USA	49	51	3-months	Six months	70	36	55.7	49; 42

Meta-analysis sample:	**N (Control) = 2555**	**N (Intervention) = 3722**	**66 years IQR:[62;70]**	**Male (69.49 %) IQR:[56;78]**

median age;mean of the intervention group only (not overall); nr – not reported; MI – Motivational Interviewing.*

Risk of bias

Six out of 20 trials reported low risk of bias (Bernocchi et al., 2018; Brodie & Inoue, 2005; Dalal et al., 2018; Freedland et al., 2015; O'Connor et al., 2009; Smeulders et al., 2009). The evaluation of two interventions was considered to be exposed to high risk of bias (lack of blinding of the assessor and lack of a pre-registered protocol (Ajiboye et al., 2015; Tomita et al., 2008)). The overall risk of bias is summarised in Figure 2. Five interventions were compared to education (Boyne et al., 2014; Brodie & Inoue, 2005; Freedland et al., 2015; Meng et al., 2016) (Ajiboye et al., 2015). The impact of the risk of bias on the results is evaluated in the sensitivity analysis.



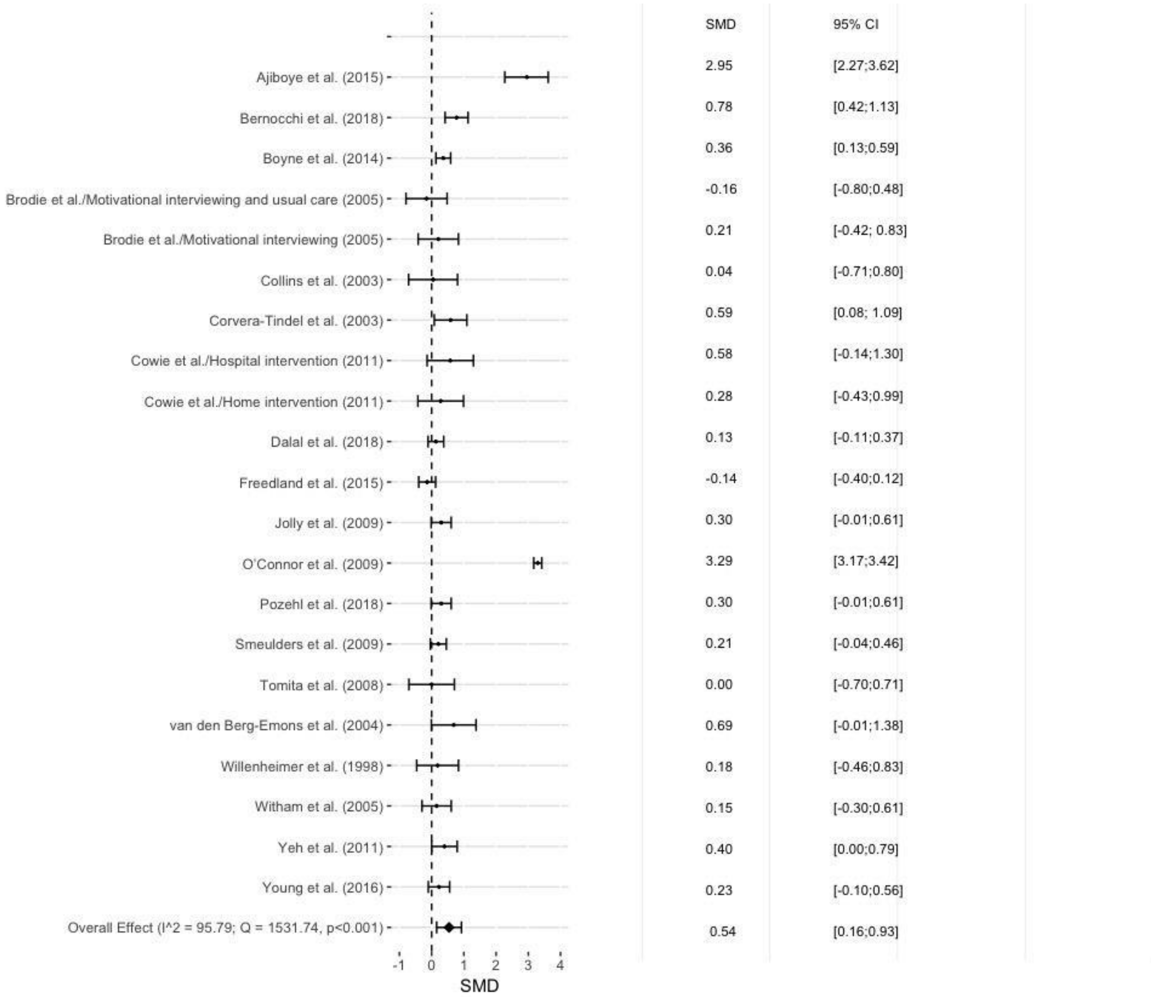
Appendix A. The risk of bias summary.

Participants' characteristics

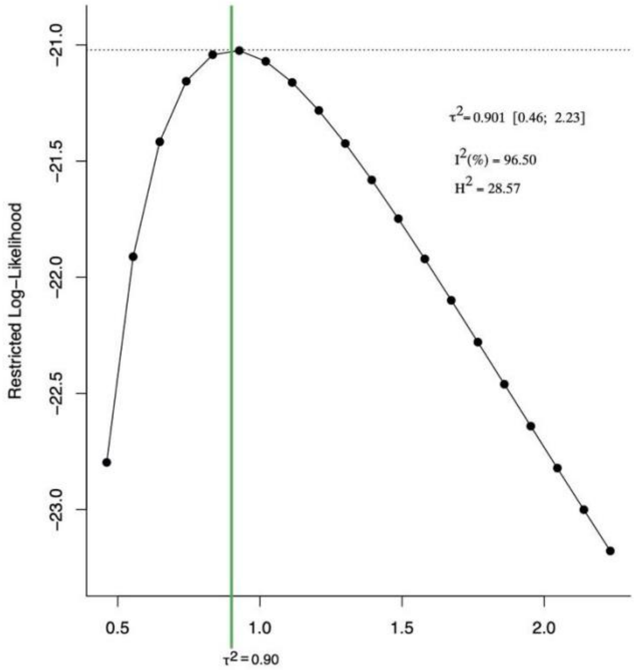
Mean age varied from 54 (Ajiboye et al., 2015) to 80 years old (Witham et al., 2005). The majority of the meta-analysis sample is male – 68.83% (Table 1). One trial delivered the intervention to patients with HF with preserved ejection fraction (HFpEF) (Dalal et al., 2018) and the rest – to those with reduced ejection fraction (HFrEF).

The main physical activity effect: post-completion

The meta-analysis found a significant overall effect as assessed at post-completion (). Significant high heterogeneity in the *estimated* effect, (I^2=95.79%, Q=1531.74,p<0.001) was present (Figure 3). The *underlying* effect is also heterogeneous (τ = 0.85) as illustrated in Figure 4. Intervention and participant characteristics were evaluated as potential predictors of the effect (exploratory meta-analysis).



Appendix A. Forrest plot illustrating overall estimated effect (SMD) and 95% CI as well as SMD and 95% CI for component trials.



Appendix A. The dispersion (tau) of the underlying main effect.

Appendix A. Intervention Characteristics

Author, year		Intervention description	Behaviour change techniques	Intervention intensity	Facilitator	mode of delivery	Theory (TCS)
Ajiboye et al., 2015	*Main intervention*	Aerobic and resistance training and education	BP/R; GT	36 session; 60-minute sessions; three a week (36 sessions)	nr	face-to-face	none
	Comparator treatment	usual care and education	PI - paradoxical instruction				
Bernocchi et al., 2018	*Main intervention*	integrated telerehabilitation home-based programme (Telereab- BHP) with personalised exercise maintenance programme	IHC; CS: IHPB; AOE; BP/R; GT; SMB; MbBOwF; FB;		Nurse tutor; physiotherapist tutor	telemonitoring of vital signs. Mini-ergometer, pedometer and diary.	none
	Comparator treatment	usual care	IHC				
van den Berg-Emons et al., 2004	*Main intervention*	aerobic exercise training	AP; BP/R; GS(B);	24 sessions, 60-minute sessions twice a week (12 weeks)	not reported	hospital-based training in groups	none
	Comparator treatment	usual care without particular advice for exercise	none	not reported	not reported	not reported	none
Boyne et al., 2014	*Main intervention*	Individually tailored e-health intervention 'Health Buddy.'	IHC; SMB; SMOB	364 sessions: daily 10-minute session (52 weeks)	HF nurse and a nurse assistant	Telemonitoring device 'Health Buddy.'	none
	Comparator treatment	education	IHC	not reported	not reported	Home-based, individual	none
Brodie et al., 2005	*Main intervention*	Motivational Interviewing	GT; IHC; PS; SC; SMB; SS(E); SS(U);	Eight sessions: Weekly 60- minute sessions (8 weeks)	A researcher without clinical qualification	home-based Face-to-face sessions	MI (TCS = 2)
	Main intervention	Motivational interviewing + education	GT; PS; SC; SMB; SS(E); SS(U)	Eight sessions: Weekly 60- minute sessions (8 weeks)	HF specialist nurse; researcher without clinical qualification	home-based Face-to-face sessions + Usual care package	MI (TCS = 2)
	Comparator treatment	education	IHC	not reported	HF specialist nurse	Usual care package	none
Collins et al., 2004	*Main intervention*	Aerobic exercise training	AOE; AP; BP/R; GS(B); GT; IHPB; RP/C	120 sessions five days a week 50 minutes (24 weeks)	Exercise physiologist or nurse	Supervised group-based	none
	Comparator treatment	usual care	none	not reported	not reported	not reported	none
Corvera-Tindel et al., 2004a	*Main intervention*	A home walking exercise programme	BP/R; GS(B); GT; MBbOwF; MOBwF; SMB	60 sessions: 60 minutes 5 days a week (12 weeks)	nurse	Home-based, Supervised	none
	Comparator treatment	usual care	MBbOwF	not reported	not reported	not reported	none
Cowie et al., 2011	*Main intervention*	hospital-based aerobic exercise training	Intervention 1: AP; BP/R; DB; GS(B); GT; IHC; IHPB; RBG; SMB; SMOB;	16 sessions: 60 minutes sessions, Twice a week eight weeks	Exercise instructor	Face-to-face, hospital-based	none
	Main intervention	home-based exercise training	Intervention 2: AP; BP/R ; DB; GS(B); GT; GTB: IHC; IHPB: SMOB;	16 sessions: 30 minutes sessions, Twice a week eight weeks	physiotherapist	home-based, individual (DVD)	none

	Comparator treatment	usual care	none	not reported	not reported	not reported	none
Dalal et al., 2018 (REACH-HF)	*Main intervention*	the Rehabilitation Enablement in Chronic Heart Failure (REACH-HF) self-care and rehabilitation intervention	BP/R; RNE; RPE; IHC; SS(E); SS(P); SS(U); GT; GS; PS; RBG; SMB	at least three face-to-face sessions; via phone - unspecified; 12 weeks	Two trained cardiac nurses	nr	SDT, CSM, CT (TCS = 5)
	Comparator treatment	usual care	IHC				
Freedland et al., 2018	*main intervention*	Integrative Cognitive Behaviour Therapy + Enhanced (with education) usual care	IHC; GS(B); AP; CS; Information on how to perform behaviour; PS; MBOwF; monitoring with feedback; Self-talk; Prompts with cues;	25 sessions; 60-minute sessions; once a week; 4 education sessions via phone (30 minutes)	Clinical phycology trainee (graduate student)	nr	CBT (TCS = 6)
	Comparator treatment	Enhanced (with education) usual care	IHC	Four education sessions via phone (30 minutes)	Nurse	nr	none
O'Connor et al., 2009 (HF-ACTION)	*Main intervention*	Aerobic exercise training + Exercise adherence facilitation intervention	AOE; AP; BP/R; CS; GS(B); GT; GTB; IHC; IHPB; PC; SMB; SMOB; SS(E); MBbOwF; SS(P); SS(U)	72 sessions, three sessions per week (24 weeks)	Physiotherapist	Facility-based group-based exercise training	TTM, SCT (TCS = 7)
	Comparator treatment	usual care	CS; GS(B); IHC; MBbOwF; SS(U);	not reported	not reported	not reported	none
Jolly et al., 2009	*Main intervention*	Aerobic and resistance exercise training	AP; BC; BP/R; DB; GS(B); GT; IHC; IHPB SMB; SS(U)	Three supervised exercise sessions; 3 home visits; 3 telephone sessions; 120 self-applied sessions (5 times a week) 20-30 minutes (24 weeks)	PA instructor	Home-based, face-to-face	none
	Comparator treatment	HF specialist nurse care	IHC	not reported	HF specialist nurse	not reported	none
Meng et al., 2016	*Main intervention*	self-management patient education program + inpatient cardiac rehabilitation	IHC; GS(B); AP; PS; RBG; SMB; FPS; IHPB; BF	Five sessions; 60-75 minutes; 2 sessions a week (approx), three-week session;	Physician; nurse; psychologist; physiotherapist	face-to-face	**nr**
	Comparator treatment	education	IHC	One session; 60 minutes	physician	face-to-face	
Pozehl et al., 2018 (HEART Camp)	*Main intervention*	multicomponent intervention Heart Failure Exercise and Resistance Training (Heart Camp)	IHTB; BP/R; BF; IEC; iHC; MOBwF; SS(U); GS(B); RBG; PS; VPaC; FB; BF; SMB	Six group-based educational sessions (adoption: 6 and months), self-administered (maintenance at 13-18 months) one session a week (18 months)	coach trainer	nr	SCT (TCS = 5)
	Comparator treatment	Enhanced (nine exercise sessions for three months)	IHPB; BP/R	nr	nr	face-to-face	none
Smeulders et al., 2009	*Main intervention*	Chronic disease management programme	AP; BC; BE; BP/R; D; DB; FB; IHC; ISRM; PS; R; RNE; SS(U); ST	Six sessions 150 minutes once a week (6 weeks)	Lay leader (HF patient); HF specialist nurse	Hospital-based group-based exercise training and classes	SLT (TCS = 8)
	Comparator treatment	usual care	none	not reported	HF specialist nurse	not reported	none
Tomita et al., 2008	*Main intervention*	Multidisciplinary Internet-based programme on management of HF	FB; IHC; IHPB; SMB	Forty-two sessions, 3.5 sessions a month for about 10 minutes. 1-year e-health intervention	Self-applied (Website)	Home-based, internet-based (website)	TTM, SST (TCS = 2)
	Comparator treatment	Usual care	none	not reported	not reported	not reported	
Willenheimer et al ., 2001	*Main intervention*	Aerobic exercise training	AP; BP/R; DB; GS(B); GT; IHPB	41 session: 2 sessions a week (15 minutes) for seven weeks: and then three sessions a week (45 minutes) for nine weeks	physiotherapist	Hospital-based, Group-based exercise training	none

	Comparator treatment	usual care + discouragement to exercise	PI	16 weeks	nr	not reported	none
Witham et al., 2005	*Main intervention*	Seated aerobic exercise training followed by seated resistance exercise training	BP/R; GS(B); GT; GTB; IHC; MOBwF; SMB; SS(U)	17-20 sessions 20- minute session Twice a week (12 weeks)	Physiotherapist	Group-based, hospital-based exercise training (supervised and home settings) Followed by home self-monitoring, self-monitoring and goal setting.	none
	Comparator treatment	usual care	IHC	nr	nr	not reported	none
Yeh et al., 2011	*Main intervention*	Exercise training (Tai Chi Mind-Body movement)	AP; BC; BP/R; DB; GS(B); IHPB; SMB	twice a week (group sessions); three times a week home sessions) one hour (group sessions); 35 minutes (home sessions) (12 weeks)	Exercise instructor	Hospital-based, Group-based exercise training	none
	Comparator treatment	usual care	none	Not reported	Video recording	Followed by home-based exercise training and monitoring	none
Young et al. 2015; 2016	*Main intervention*	Patient Activation Intervention on self-management in HF (Patient AcTivated Care at Home: PATCH)	IHC; DB; IHPB; AOE (scale?); SMOB; ;GS(B); IAwCB; SC; VC; MBbOwF; NSI	12 sessions (45 minutes); one in a hospital and then twice a week for the first two weeks, once a week for weeks 3–6, and every other week for weeks 7–12 (12 weeks)	Advanced practice nurse	one session face-to-face; telephone	none
	Comparator treatment	Usual care	IHC	50-minute one session	nurse	face-to-face	none

Note: TCS – Theory Coding Scheme; nr – not reported; MI – Motivational Interviewing, SDT – Self-determination theory; CSM CT—Control Theory; CBT—Cognitive Behavioural Therapy; TTM – Transtheoretical Model of Change; SCT—Social Cognitive Theory; SLT – Social Learning theory; SST; AOE – 12.5. Adding objects to the environment; AP – 1.4. Action planning; BC –12.6. Body changes; BE – 4.4. Behavioural experiments' /R – 8.1. Behavioural practice/rehearsal; BioF - Biofeedback; CS – 9.2. Credible source; DbCBaG - 1.6. Discrepancy between current behaviour and goal; D – 12.4. Distraction; DB – 6.1. Demonstration of the behaviour; FB – 2.2. Feedback on behaviour; FPS - 15.3. Focus on past success; F/R - 13.2. Framing/reframing; GS(B) – 1.1. Goal setting (behaviour); GT – 8.7. Graded tasks; GTB – 8.6. Generalisation of target behaviour; A – 4.2. Information about antecedents; "IEC - 5.6. Information about emotional consequences; "IHC – 5.1 Information about health consequences; IHPB – 4.1. Instruction on how to perform the behaviour; IAwCB - 13.5. Identity associated with changed behaviour; ISRM – 13.1. Identification of self as a role model; MBbOwF - 2.5. Monitoring of behaviour by others without feedback; MOBwF – 2.5. Monitoring of outcomes of behaviour without feedback; NSI - non-specific incentive; NSR – 10.3. Non-specific reward; P/C – 7.1. Prompts/cues; PS – 1.2. Problem-solving; R – 4.3. Reattribution; RBG – 1.5. Review behaviour goal(s);RNE –11.2. Reduce negative emotions; RP/C – 7.3. Reduce prompts cues; RPE - 12.1. Restructuring the physical environment; SC – 6.2. Social comparison; SMB – 2.3. Self-monitoring of behaviour; SMOB – 2.4. Self-monitoring of outcome(s) of behaviour; SS(E) – 3.3. Social support (emotional); SS(P) –3.2. Social support (practical); SS(U) – 3.1. Social support (unspecified); ST – 15.4. Self-talk; VPaC - 15.1. Verbal persuasion about capability; VC - 16.3. Vicarious consequences.

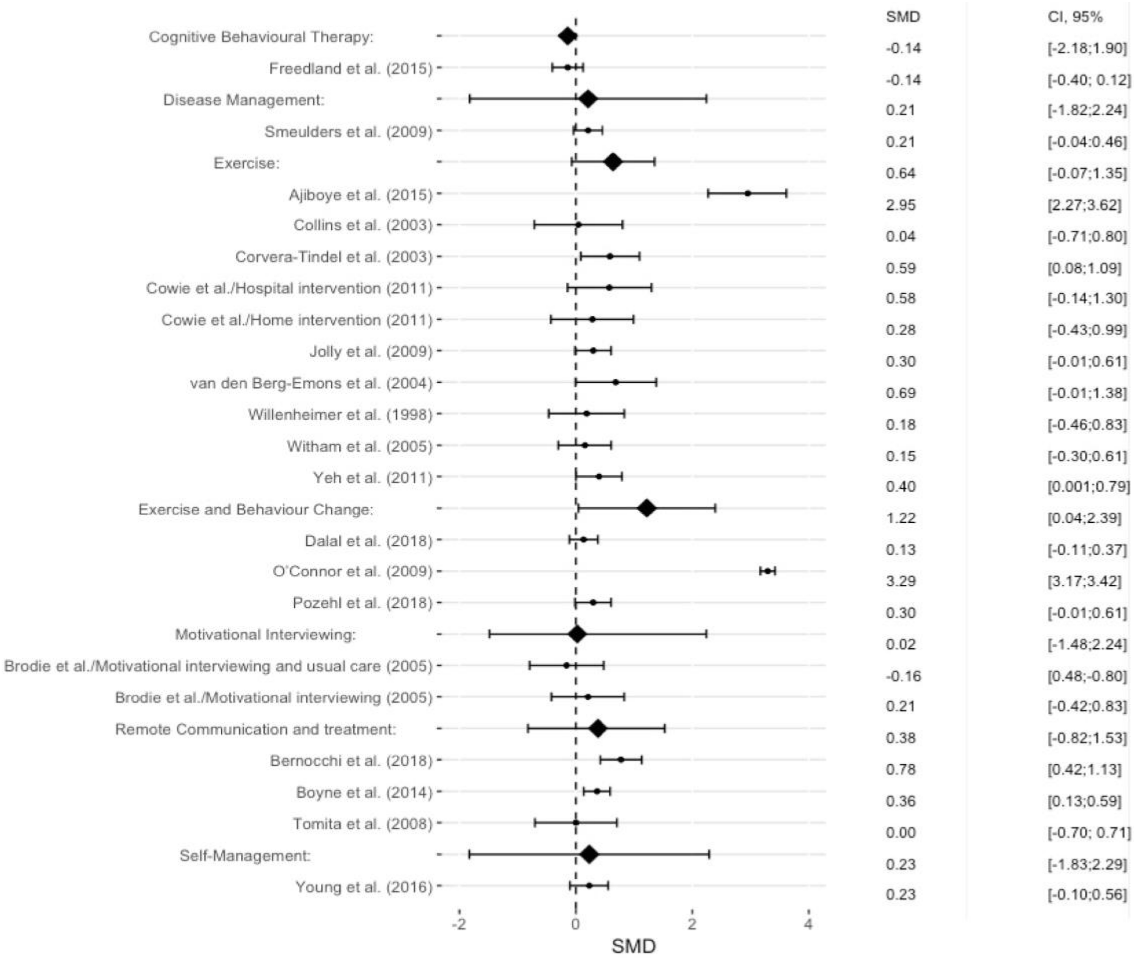
The reported interventions were classified as Cognitive Behavioural Therapy, Disease Management, Exercise, Exercise and Behaviour Change, Motivational Interviewing Remote Communication and Treatment and Self-Management. This classification was formulated based on the provided intervention descriptions.

Appendix A.. Efficacy (The standardised mean difference) of the interventions moderated by the general approach.

General Approach	Number of interventions		CI, 95%
Cognitive Behavioural Therapy	k = 1 [28]	-0.14	[-2.18;1.90]
Disease Management	k = 1 (Smeulders et al., 2009)	0.21	[-1.82;2.24]
Exercise	k = 10 (Ajiboye et al., 2015; Collins et al., 2004; Corvera-Tindel, Doering, Woo, et al., 2004; Cowie et al., 2011; Jolly et al., 2009; van den Berg-Emons et al., 2004; Willenheimer et al., 1998; Witham et al., 2005; Yeh et al., 2011)	0.64	[-0.07;1.35]
Exercise and Behaviour Change	k = 3 (Dalal et al., 2018; O'Connor et al., 2009; Pozehl et al., 2018)	1.22*	[0.04;2.39]
MI	k = 2 (Brodie & Inoue, 2005)	0.02	[-1.48;1.53]
Remote Communication and Treatment	k = 3 (Bernocchi et al., 2018; Boyne et al., 2014; Tomita et al., 2008)	0.38	[-0.82;1.58]
Self-Management	k = 1 (Young et al., 2016)	0.23	[-1.83;2.29]

Heterogeneity of the estimated effect:
Standard deviation of the underlying true effect:

*p<0.05



Appendix A. Forest plot illustrating the standardised mean differences (SMD, 95 %CI)moderated by the general approach

Appendix A. Intervention Characteristics Associated with Efficacy

Intervention Characteristics	SMD	CI, 95%
Behaviour change techniques:		
Prompts/cues Definition: Introduce or define environmental or social stimulus to promote or cue the behaviour. Examples: frequent phone calls by a health professional/ post or email reminders	3.29	[1.97;4.62]
Credible source Definition: resent verbal or visual communication from a credible source in favour of or against the behaviour. Examples: Explicit, detailed and salient advice from a health professional to engage in physical activity.	2.08	[0.95;3.22]
Adding objects to the environment Definition: Add objects to the environment in order to facilitate the performance of the behaviour. Examples: Provision of a treadmill, weights, step, or stationary bicycle.	1.47	[0.41;2.53]
Generalisation of the target behaviour Definition: Advice to perform the desired behaviour, which is already performed in a particular situation, in another situation. Examples: Encouragement to engage in an exercise in home settings.	1.32	[0.22;2.41]
Monitoring of behaviour by others without feedback Definition: Observe or record behaviour with the person's knowledge as part of a behaviour change strategy. Examples: Physiotherapist informs participants that their physical activity levels will be monitored using accelerometers and telemonitoring devices.	1.02	[0.05;1.98]
Self-monitoring of outcome(s) of behaviour Definition: Establish a method for the person to monitor and record the outcome(s) of their behaviour as part of a behaviour change strategy. Examples: Monitoring reduced pain symptoms and dyspnoea as a result of physical activity.	0.79	[0.06;1.52]
Graded tasks Definition: Set easy-to-perform tasks, making them increasingly difficult, but achievable until the behaviour is performed. Examples: Gradual increase in the level of exertion as assessed using the Borg scale.	0.73	[0.22;1.24]
Behavioural practice/rehearsal Definition: Prompt practice or rehearsal of the performance of the behaviour one or more times in a context or at a time when the performance may not be necessary. Examples: Exercise training (individual or in a group).	0.72	[0.26;1.18]
Action planning Definition: prompt, detailed planning of performance of the behaviour (must include at least one of context, frequency, duration and intensity). Examples: plan when, where, how much and at what intensity the participant will perform the exercise.	0.62	[0.03;1.21]
Goal setting (behaviour) Definition: set or agree on a goal defined in terms of the behaviour to be achieved. Examples: Set a goal to complete 30 minutes of exercise (brisk walking) at the vagarious intensity in future.	0.56	[0.03;1.08]
Setting: Centre-based interventions	0.98	[0.35;1.62]
Mode of delivery: Group-based interventions	0.89	[0.29;1.50]
Facilitator: Physiotherapist	0.84	[0.03;1.65]

Note: Definitions are from Michie et al. (Susan Michie et al., 2013).

The intervention characteristics that significantly moderated the effect are presented in Table 2. Interventions included a mean of 8.90 (3.77) strategies (BCTs). The following strategies were associated with large to moderate effects: Prompts/cues, Credible source, Adding objects to the environment, Generalisation of target behaviour, Monitoring of behaviour by others without feedback, Self-monitoring of outcome(s) of behaviour, Graded tasks, Behavioural practice/rehearsal, Action planning, Goal setting (behaviour).

Interventions were delivered at home (n = 8), in a hospital/clinic (n = 8), or both (n =5). Only centre-based delivery significantly moderated the efficacy of the included interventions. Interventions were facilitated by physiotherapist (n = 6), researcher (n =2), lay leader (n =1), advanced (n =1), HF (n =4) or general practice (n =9) nurse, exercise instructor (n=3), a psychologist (n =1), or clinical psychology trainee (n =1). The presence of a physiotherapist significantly increased the efficacy of the interventions. The duration varied from one day to 72 weeks (mean contact time = 1849.38 mins (SD = 1716.40). Intervention duration was not associated with the efficacy. Seven interventions were based on a behaviour change theory: Motivational Interviewing (n=2), Social Cognitive Theory (n=1), Social Learning Theory (n=1), Transtheoretical Model of Change (TTM, n=1), and a hybrid of several theories (n =2), such as Self-determination Theory, Leventhal's Common Sense Model; Control Theory; and TTM, Social Support Theory, and a Mass Communication Theory. The characteristics of the participant samples, such as mean age, the proportion of males, mean LVEF (%), NYHA class and aetiology were not significantly associated with the efficacy of the identified interventions.

Follow-up

The included trials assessed physical activity at 2-months, 6-month, 12-month and 30-months follow-up. The overall short-term effect was non-significant at 6-months, and 12-month, Due to the small number of trials reporting follow-up assessment, it was not feasible to evaluate the long-term effects associated with the individual intervention characteristics.

Sensitivity Analysis

Active Comparator

Interventions were compared to usual care (Bernocchi et al., 2018; Collins et al., 2004; Corvera-Tindel, Doering, Woo, et al., 2004; Cowie et al., 2011; Dalal et al., 2018; Jolly et al., 2009; O'Connor et al., 2009; Pozehl et al., 2018; Smeulders et al., 2009; Tomita et al., 2008; Witham et al., 2005; Yeh et al., 2011; Young et al., 2016); education delivered by a HF specialist nurse (Boyne et al., 2014; Brodie & Inoue, 2005; Freedland et al., 2015; Meng et al., 2016) or unspecified health professional (Ajiboye et al., 2015), and discouragement to exercise (Willenheimer et al., 1998). The comparator arms included a mean of 1.15 (SD=1.49) BCTs. The exclusion of trials with an active comparator treatment did not significantly change the results (Table 5).

HF-ACTION Trial

The exclusion of the large (N= 2331) trial (O'Connor et al., 2009) with a young (56 years old) sample resulted in the significant decrease of the overall effect. The effect estimates for Exercise and Behaviour Change Approach, Prompts/cues, Credible source, Adding objects to the environment, Generalisation of target behaviour, Monitoring of behaviour by others without feedback, Self-monitoring of outcome(s) of behaviour, Action planning, Goal setting (behaviour) are sensitive to the inclusion of the trial.

High risk of bias

The exclusion of high bias trials indicated that Exercise Approach effect is overestimated. The effects of the following strategies are underestimated: Social Support (emotional), Social Support (practical), TCS score, Information about health consequences, Information on how to perform behaviour. The exclusion of both the HF-ACTION and high-risk of bias trials suggest that Exercise and Remote Communication and Treatment yield significant small and medium effects, respectively; and that the estimates for the delivery by nurse, telehealth, and Biological feedback are sensitive to these exclusions.

Small study bias

The Egger's test suggests a lack of publication and small study bias (test for funnel plot asymmetry.

Appendix A. The sensitivity analysis results.

EXCLUDED TRIALS	Overall effect	General Approach	Efficacious intervention characteristics
Trials with the education comparator (Boyne et al., 2014; Brodie & Inoue, 2005; Freedland et al., 2015; Meng et al., 2016) (Ajiboye et al., 2015)	SMD = 0.31, 95%CI [0.21; 0.40] ***	**Exercise: SMD = 0.34 , 95%CI [0.18; 0.51];** **Remote communication and treatment:** **SMD = 0.42, 95%CI [0.24; 0.60];** Exercise and behaviour change: SMD = 0.21, 95%CI [0.004; 0.41]; Disease Management: SMD = 0.21, 95%CI [-0.03; 0.45]; Self-Management: SMD = 0.23, 95%CI [-0.17; 0.62].	No change in the significance of the effects associated with individual intervention or participant characteristics
HF-ACTION trial (O'Connor et al., 2009)	SMD = 0.37, 95% CI: [0.10; 0.63]*	**Exercise: SMD = 0.56, 95%CI [0.18; 0.94];** Remote communication and treatment: SMD =0.41, 95%CI [-0.29; 1.11]; MI: SMD = 0.03, 95%CI [-0.89; 0.94]; **Exercise and behaviour change:** **SMD = 0.21, 95%CI [-0.59; 1.01];**	Behavioural Practice and Rehearsal * Graded task * Group-based * Centre-based *

		CBT: SMD = 0.21, 95%CI [-0.91; 1.33]; Disease Management: SMD =0.23, 95%CI [-0.95; 1.41].	
High Risk of Bias trials (Ajiboye et al., 2015; Tomita et al., 2008)	SMD = 0.4578 95%CI [0.0903 0.8252 *	Exercise: SMD =0.36, 95%CI [-0.2; 0.91]; Remote communication and treatment: SMD = 0.56, 95%CI [-0.57; 1.7]; MI: SMD = 0.03, 95%CI [-1.16; 1.21]; Exercise and behaviour change: SMD = 1.27, 95%CI [0.47; 2.07]***; CBT: SMD = 0.21, 95%CI [-1.38; 1.8]; Disease Management: SMD =0.23, 95%CI [-1.39 1.85].	**Social Support (emotional)** * **Social Support (practical)** ** **TCS score** * Monitoring of behaviour by others w/o feedback* Credible source*** Adding objects to the environment *** Self-monitoring of outcome(s) of behaviour* **Self-monitoring of behaviour** * **Information about health consequences** * **Information on how to perform behaviour** *

			Graded tasks * Action Planning * Goal setting (behaviour) * Behavioural Practice and Rehearsal**
HF-ACTION trial (O'Connor et al., 2009) and High Risk of Bias trials	SMD = 0.2670 95%CI [0.1549 0.3790 ***	**Exercise: SMD=0.35, 95% CI [0.15; 0.54]*;** **Remote communication and treatment: SMD=0.47, 95%CI [0.24;0.70]*;** MI: SMD=0.03, 95%CI [-0.46;0.52]; **Exercise and behaviour change: SMD= 0.21; 95%CI:[-0.07; 0.49];** CBT SMD= 0.21, 95%CI:[-0.15; 0.57] Disease Management SMD= 0.23, 95%CI:[-0.25; 0.71].	**Nurse** *** **Telehealth**** **Biological Feedback*** Credible source * Self-monitoring of outcomes of behaviour* **Self-monitoring of behaviour** ** **Demonstration of the behaviour** ** **Information about health consequences** ** Graded tasks ** Action Planning ** Goal setting (behaviour)***

	Behavioural Practice and Rehearsal***

Note: *p<0.05; **p<0.01,* p<0.001. The changes in the findings are in bold.**

Appendix A1: Trim and Fill test results: the meta-analysis of Initial search

(1) Trim and Fill test methods

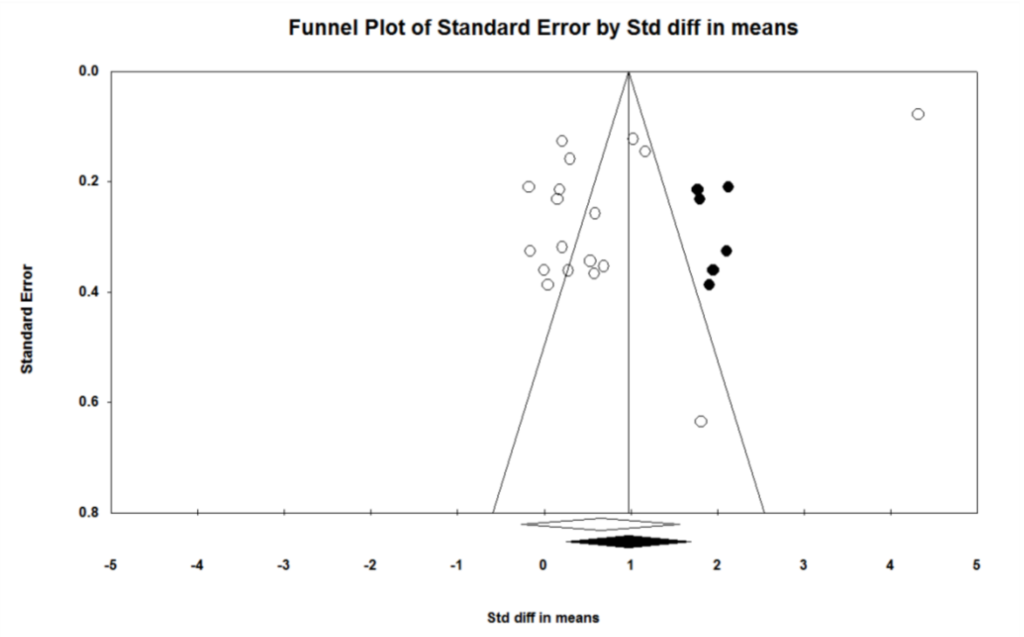
Trim and Fill is an informative method for assessing publication bias, because the test assesses the presence of publication bias as well as adjusts for it by estimating what the overall effect may have been if the non-observed trials would be included. Based on the recommendations (Begg, 1994) the results of the meta-analysis were not adjusted by imputing the 'non-observed trials'; and the non-observed trials were not used in drawing an overall effect.

The Trim & Fill method imputes trials to the right of the mean effect. Determining where the missing (non-observed) trials are likely to fall, the test then adds the non-observed trials to the analysis, and then re-computes the combined effect. 'Trim and Fill' initially trims the asymmetric trials from the left-hand side to locate the unbiased effect and then fills the plot by re-inserting the trimmed trials on the left as well as their imputed counterparts to the right of the mean effect.

Classic Fail-safe N could not be used for this review because the overall result of the meta-analysis was non-significant. Fail-safe N assumes that some non-significant trials are missing from the analysis and that these trials, if included, would nullify the observed effect. The Trim and Fill method was chosen over an alternative method, called Beg and Mazumdar Rank Correlation Test (1994), because a non-significant correlation produced by the latter may be due to low statistical power and cannot be taken as evidence that bias is absent. In addition, a significant correlation produced by the rank correlation test suggests that bias exists but does not directly address the implications of this bias, making it a less informative test.

Asymmetry in a funnel plot may arise from not only the fact that positive results are more likely to be published but from inherent between-study heterogeneity (Lau et al., 2006; Sutton et al., 2005). Large trials that receive more funding are more likely to test interventions that have a well-thought content, and are delivered more rigorously or for a longer period of time (e.g. HF-ACTION trial). The asymmetry may have been caused by systematic differences in the content of interventions described earlier. Therefore, the results of the publication bias assessment should be interpreted with caution.

The funnel plot is illustrated in Figure 4.9. The observed overall effect is illustrated as an open diamond and the estimated overall effect, which included imputed trials, as a closed diamond. There was a clear asymmetry in the funnel plot (p<0.01, using Eger's method for testing funnel plots asymmetry. There was a significant negative intercept (B0=-12.12867, 95% CI: -20.16023, -4.09711, t=3.20133, df=16, p<0.005).



Appendix A1. **Funnel plot illustrating SMD against Standard Error of the observed (open circle) and imputed (closed circle) trials.**

The Trim and Fill method suggested that 6 trials are missing. Under the random effects model using the Trim and Fill method, the imputed point estimate was 0.97571 ([95% CI: -0.25582, 1.69560], $p<0.05$). Therefore, if imputed studies were included in the analysis, the overall effect would increase from 0.58 to 0.97 and would reach the threshold of statistical significance.

Appendix B. AMSTAR 2 online evaluation form result

AMSTAR 2 online evaluation form result: Interventions designed to increase physical activity in HF is a High-quality review

1. Did the research questions and inclusion criteria for the review include the components of PICO?	Yes
	Partial Yes
• **Did the report of the review contain an explicit statement that the review methods were established prior to the conduct of the review and did the report justify any significant deviations from the protocol?** Reviewer did not provide the details about heterogeneity analysis as she did not know ahead what methods would be appropriate to use	
3. Did the review authors explain their selection of the study designs for inclusion in the review?	Yes Yes
4. Did the review authors use a comprehensive literature search strategy? Only provided reasons for exclusion but did not supplement the full list of excluded trials (available upon request).	Partial Yes Yes Yes Yes Yes

5. Did the review authors perform study selection in duplicate?	Yes Yes
6. Did the review authors perform data extraction in duplicate?	Yes Yes
7. Did the review authors provide a list of excluded studies and justify the exclusions?	No
8. Did the review authors describe the included studies in adequate detail?	Yes
9. Did the review authors use a satisfactory technique for assessing the risk of bias (RoB) in individual studies that were included in the review? **RCT**	 Yes
10. Did the review authors report on the sources of funding for the studies included in the review?	Yes Yes
11. If meta-analysis was performed did the review authors use appropriate methods for statistical combination of results? **RCT**	 Yes
12. If meta-analysis was performed, did the review authors assess the potential impact of RoB in individual studies on the results of the meta-analysis or other evidence synthesis?	Yes Yes Yes
13. Did the review authors account for RoB in individual studies when interpreting/ discussing the results of the review?	Yes Yes

14. Did the review authors provide a satisfactory explanation for, and discussion of, any heterogeneity observed in the results of the review?	Yes Yes
15. If they performed quantitative synthesis did the review authors carry out an adequate investigation of publication bias (small study bias) and discuss its likely impact on the results of the review?	Yes Yes
16. Did the review authors report any potential sources of conflict of interest, including any funding they received for conducting the review?	Yes Yes

Citation: Shea BJ, Reeves BC, Wells G, Thuku M, Hamel C, Moran J, Moher D, Tugwell P, Welch V, Kristjansson E, Henry DA. AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. BMJ. 2017 Sep 21;358:j4008.

Appendix C. Meta-analysis of the RCTs evaluating physical activity interventions: search strategy

MEDLINE (via OVID) search strategy
1. exp HF/
2. exp congestive HF/
3. cardiac failure.mp.
4. exp HF, Systolic/
5. cardiac incompetence.mp.
6. cardiac decompensation.mp.
7. cardiac insufficiency.mp.
8. cardial insufficiency.mp.
9. chronic HF.mp.
10. chronic heart insufficiency.mp.
11. heart decompensation.mp.
12. heart insufficiency.mp.
13. myocardial failure.mp.
14. myocardial insufficiency.mp.
15. (heart adj3 fail*).tw.
16. diastolic dysfunction.mp.
17. systolic dysfunction.mp.
18. exp Cardiac Output/
19. exp Ventricular Dysfunction/
20. congestive HF.mp.
21. congestive cardiac failure.mp.
22. exp HF, Diastolic/
23. (heart adj3 dysfunction*).tw.
24. (cardiac adj3 dysfunction*).tw.
25. left ventricular dysfunction.tw.
26. (cardiac adj3 fail*).tw.
27. or/1-26
28. physical activity.tw.
29. exp Motor Activity/
30. physical activity.mp.
31. exp Exercise/
32. physical exercise.mp.
33. exercise.mp.
34. exp Walking/
35. walking.mp.
36. exp Life Style/
37. life style changes.mp.
38. daily activity.mp.
39. daily physical activity.mp.
40. exercise programme.mp.
41. exercise program.mp.
42. physical training.mp.
43. exp "Physical Education and Training"/
44. exp Exercise Therapy/
45. exp Leisure Activities/
46. leisure activities.mp.
47. exp Swimming/
48. swimming.mp.
49. exp Running/

50. running.mp.
51. exp Exercise Tolerance/
52. exercise tolerance.mp.
53. exercise capacity.mp.
54. exp Exercise Test/
55. cardiac rehabilitation.mp.
56. guideline adherence.tw.
57. patient complince.tw.
58. (physic* adj3 activ*).tw.
59. exercis*.tw.
60. fitness.tw.
61. walking.tw.
62. daily physical activity.tw.
63. exercise program*.tw.
64. resistance training.tw.
65. aerobic exercise.tw.
66. exp Bicycling/
67. oxygen consumption.mp.
68. endurance exercise.tw.
69. cardiac rehabilitation.tw.
70. 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41 or 42 or 43 or 44 or 45 or 46 or 47 or 48 or 49 or 50 or 51 or 52 or 53 or 54 or 55 or 56 or 57 or 58 or 59 or 60 or 61 or 62 or 63 or 64 or 65 or 66 or 67 or 68 or 69
71. 27 and 70
72. behavioural intervention.mp.
73. behavioral intervention.mp.
74. intervention.mp.
75. exp "Early Intervention (Education)"/
76. behaviour change technique.mp.
77. strategies.mp.
78. behavio$r change.tw.
79. behavio$r change adj3 technique.tw.
80. behaviour change adj3 techniques.tw.
81. education.tw.
82. exp Health Education/ or Education/
83. behaviour change intervention.mp.
84. exp Risk Reduction Behavior/
85. behavio* change adj3 interv*.tw.
86. health behavio$r adj3 chang*.tw.
87. intervention.tw.
88. psychological adj3 intervention.tw.
89. psychological intervention.mp.
90. exp Counseling/
91. exp Psychotherapy/
92. BCT.mp.
93. Health adj3 promot*.tw.
94. behavio$r therapy.tw.
95. self-care.tw.
96. patient adj3 care.tw.
97. 72 or 73 or 74 or 75 or 76 or 77 or 78 or 79 or 80 or 81 or 82 or 83 or 84 or 85 or 86 or 87 or 88 or 89 or 90 or 91 or 92 or 93 or 94 or 05 or 96
98. 27 and 70 and 97
99. exp Randomized Controlled Trial/
100. randomized controlled trial.mp.
101. randomised controlled trial.mp.
102. Clinical Trials as Topic/
103. controlled trial.tw.

104. trial.tw.
105. 99 or 100 or 102 or 103 or 104
106. 27 and 70 and 97 and 105
EMBASE (via OVID) search strategy
1. exp HF/
2. HF.mp.
3. heart decompensation.mp.
4. heart insufficiency.mp.
5. cardiac failure.mp.
6. cardiac incompetence.mp.
7. cardiac decompensation.mp.
8. cardiac insufficiency.mp.
9. exp heart output/
10. cardiac output.mp.
11. exp diastolic dysfunction/
12. exp congestive HF/
13. diastolic dysfunction.mp.
14. exp systolic dysfunction/
15. exp heart left ventricle failure/
16. heart left ventricle failure.mp.
17. cardial insufficiency.mp.
18. chronic HF.mp.
19. chronic heart insufficiency.mp.
20. decompensation,heart.mp.
21. myocardial failure.mp.
22. myocardial insufficiency.mp.
23. (heart adj3 fail*).tw.
24. (heart adj3 dysfunction*).tw.
25. left ventricular dysfunction.tw.
26. (cardiac adj3 dysfunction*).tw.
27. (cardiac adj3 fail*).tw.
28. ventricular dysfunction.mp.
29. chronic cardiac failure.mp.
30. congestive cardiac failure.mp.
31. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30
32. exp physical activity/
33. physical exercise.mp.
34. physical activity.mp.
35. exercise.mp.
36. exp aerobic exercise/
37. aerobic exercise.mp.
38. exp resistance training/
39. resistance training.mp.
40. exercise training.mp.
41. exp daily life activity/
42. exp walking/
43. exp motor activity/
44. daily physical activity.mp.
45. exp motor activity/
46. exp leisure/
47. leisure activities.mp.
48. exp heart rehabilitation/
49. cardiac rehabilitation.mp.
50. exercise program.mp.
51. exercise programme.mp.
52. exp fitness/

53. exp swimming/
54. exp sport/
55. exp endurance training/
56. (physic* adj3 activ*).tw.
57. physical activity.tw.
58. exercis*.tw.
59. walk*.tw.
60. (daily adj5 physic adj5 activ*).tw.
61. guideline adherence.mp.
62. patient adherence.mp.
63. patient guideline.mp.
64. adhere* adj3 guideline*.tw.
65. 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41 or 42 or 43 or 44 or 45 or 46 or 47 or 48 or 49 or 50 or 51 or 52 or 53 or 54 or 55 or 56 or 57 or 58 or 59 or 60 or 61 or 62 or 63 or 64
66. 31 and 65
67. exp intervention study/
68. intervention.mp.
69. exp health promotion/
70. exp behavior change/
71. behavioral intervention.mp.
72. behaviour change.mp.
73. exp behavior change/
74. psychological intervention.mp.
75. exp patient education/
76. exp counseling/
77. exp patient counseling/
78. behav* change.tw.
79. (change adj3 behavio$r).tw.
80. intervention.tw.
81. health promotion.tw.
82. behavio$r change technique*.tw.
83. behavio$r change strateg*.tw.
84. BCT.tw.
85. psycholog*.tw.
86. exercis*.tw.
87. cardiac rehabilitation.tw.
88. 67 or 68 or 69 or 70 or 71 or 72 or 73 or 74 or 75 or 76 or 77 or 78 or 79 or 80 or 81 or 82 or 83 or 84 or 85 or 86 or 87
89. 31 and 61 and 82
90. randomi$ed controlled trial.tw.
91. randomized controlled trial/
92. clinical trial/
93. controlled study/
94. RCT.mp.
95. 89 or 90 or 92 or 93 or 94
96. 31 and 65 and 88 and 95

HEED (via EBSCOhost)

1. SU HF
2. TX congestive HF
3. TX cardiac failure
4. TX cardiac insufficiency
5. TX diastolic dysfunction
6. TX systolic dysfunction
7. TX Cardiac Output
8. TX Ventricular Dysfunction
9. HF
10. (ZE "HF diagnosis")

11. (ZE "HF epidemiology")
12. (ZW "HF")
13. (ZE "HF prevention & control")
14. (ZE "HF psychology")
15. (ZE "HF rehabilitation")
16. (ZW "congestive HF")
17. (ZW "cardiomyopathy")
18. (ZE "ventricular dysfunction, left therapy")
19. (ZE "ventricular dysfunction therapy")
20. (ZE "ventricular dysfunction, left diagnosis")
21. S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7 OR S8 OR S9 OR S10 OR S11 OR S12 OR S13 OR S14 OR S15 OR S16 OR S17 OR S18 OR S19 OR S20
22. (ZE "physical and rehabilitation medicine economics")
23. (ZE "physical education and training economics")
24. (ZE "physical endurance physiology")
25. (ZE "physical fitness physiology")
26. (ZE "exercise physiology")
27. (ZE "exercise psychology")
28. (ZE "exercise therapy economics")
29. (ZE "exercise therapy methods")
30. (ZE "walking economics")
31. (ZE "walking physiology")
32. (ZW "physical activity")
33. (ZW "physical exercise programmes")
34. (ZW "exercise")
35. (ZW "walking")
36. (ZW "lifestyle - healthy")
37. (ZW "cardiac rehabilitation")
38. SU physical activity
39. S22 OR S23 OR S24 OR S25 OR S26 OR S27 OR S28 OR S29 OR S30 OR S31 OR S32 OR S33 OR S34 OR S35 OR S36 OR S37 OR S38
40. S21 AND S39

AMED (via OVID) search strategy

1. exp HF congestive/
2. HF.mp.
3. heart disease/ or exp heart valve disease/
4. cardiac insufficiency.mp.
5. cardiac dysfunction.mp.
6. ventricular dysfunction.mp.
7. systolic dysfunction.mp.
8. diastolic dysfunction.mp.
9. (heart adj3 dysfunction*).af.
10. (heart adj3 fail*).af.
11. (cardiac adj3 dysfunction*).af.
12. (cardiac adj3 fail).af.
13. chronic HF.af.
14. chronic HF.mp.
15. cardiac incompetence.af.
16. cardiac incompetence.mp.
17. cardiac insufficiency.af.
18. cardiac insufficiency.mp.
19. exp Cardiac output/
20. cardiac decompensation.mp.
21. cardiac decompensation.af.
22. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21
23. exp Exercise/
24. Exercise/ or exercise.mp.

25. exp Physical fitness/
26. daily physical activity.mp.
27. exp Walking/
28. exp Rehabilitation/
29. cardiac rehabilitation.mp.
30. exp Leisure activities/
31. exp Resistance training/
32. exp Exercise therapy/
33. resistance training.mp.
34. exp Muscle strength/ or resistance training.mp.
35. aerobic exercise.af.
36. exercise training.af.
37. exercise program*.mp.
38. exp Exercise therapy/
39. endurance exercise.mp.
40. exp Bicycling/
41. exp Oxygen consumption/
42. (physic* adj3 activ*).af.
43. physical activity.af.
44. (daily adj5 physic* adj5 activ*).af.
45. exercise*.af.
46. daily life.af.
47. physical training.af.
48. physical training.mp.
49. exercise tolerance.mp.
50. exercise tolerance.af.
51. exercise capacity.af.
52. exercise capacity.mp.
53. ventricular dysfunction.tw.
54. ventricular dysfunction.mp.
55. 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41 or 42 or 43 or 44 or 45 or 46 or 47 or 48 or 49 or 50 or 51 or 52 or 53 or 54
56. 22 and 55
57. exp Treatment outcome/
58. intervention.mp.
59. exp Health promotion/
60. health promotion.mp.
61. exp Behavior therapy/
62. behavioral intervention.mp.
63. BCT.af.
64. beavio?r change.af.
65. behavio$r change intervention.af.
66. behavio$r change technique*.af.
67. health behavio$r change.af.
68. health education.mp.
69. health behavio$r change.mp.
70. health education.mp.
71. counseling.mp.
72 exp Counseling/
73 counseling.af.
74. psychotherapy.mp.
75.psycholog* adj3 interven*.af.
76. 57 or 58 or 59 or 60 or 61 or 62 or 63 or 64 or 65 or 66 or 67 or 68 or 69 or 70 or 71 or 72 or 73 or 73 or 74 or 75
77. 22 and 55 and 76
78. randomized controlled trial.af.
79. exp Randomized controlled trials/

80. randomised controlled trial.mp.
81. randomized controlled trial.mp.
82. exp Clinical trials/
83. controlled trial.mp.
84. 78 or 79 or 80 or 81 or 82 or 83
85. 22 and 55 and 76 and 84

CINAHL Search Strategy (via EBSCOhost)

1.(MM "HF+")
2."HF"
3.(MM "Cardiac Output, Decreased")
4.(MM "Ventricular Dysfunction+")
5.heart N5 fail*
6.cardi* N4 dysfunction*
7.heart N5 dysfunction*
8."congestive HF"
9. "cardiac fail*"
10. "systolic HF"
11. "cardiac incompetence"
12. "cardiac decompensation"
13. "cardiac insufficiency"
14. "chronic HF"
15. "cardial insufficiency"
16. "myocardial failure"
17. "myocardial insufficiency"
18. "heart N3 fail*"
19. "diastolic dysfunction*"
20. "Systolic dysfunction*"
21. "heart N3 dysfunction*"
22. "cardiac dysfunction*"
23. OR/1-22
24.(MH "Behavioral Changes")
25.(MH "Life Style Changes")
26. (MM "Self Care+")
27."Self-management"
28. “Intervention”
29.(MM "Early Intervention+")
30. (MM "Patient Care+")
31. (MM "Rehabilitation+")
32. (MM "Home Rehabilitation+")
33. (MM "Rehabilitation, Cardiac+")
34. (MM "Rehabilitation, Community-Based")
35. (MH "Physical Education, Adapted")
36. (MH "Behavioral Objectives")
37. (MH "Psychosocial Adjustment: Life Change (Iowa NOC)
38. (MH "Change Management")
39. (MH "Behavior Management (Iowa NIC)")
40. (MH "Health Behavior")
41. (MH "Phychotherapy+")
42. "Behavio$ral intervention"
43. "Behavio$change technique*"
44. "Behavio$r change"
45. "Counselling"
46. "Psychotherapy"
47. OR/24-46
48. (MH "Physical Activity")

49. (MH "Sports+")
50. (MH "Activities of Daily Living+")
51. (MH "Exercise+")
52. (MH "Leisure Activities+")
53. (MH "Physical Fitness+")
54. (MH "Movement")
55. (MH "Aerobic Exercise+")
56. (MH "Swimming")
57. (MH "Rehabilitation, Cardiac")
58. (MH "Resistance training")
59. (MH "Sports Specific Training")
60. (MH "Group Exercise")
61. Physical N5 activ*
62. Exercis*
63. OR/48-62
64. (MH "Randomized Controlled Trials")
65. "Randomi$ed controlled trial"
66. "Clinical trial"
67. OR/64-66
68. 23 AND 47
69. 23 AND 47 AND 63
70. 23 AND 47 AND 63 AND 67

Cochrane Library Search strategy

1. MeSH descriptor: [HF] explode all trees
2. Cardiomyopathy, Dilated (this term only)
3. MeSH descriptor: [Ventricular Dysfunction] explode all trees
4. MeSH descriptor: [Cardiac Output, Low] this term only
5. MeSH descriptor: [HF, Diastolic] explode all trees
6. MeSH descriptor: [HF, Systolic] explode all trees
7. (Congestive or chronic) near/3 "HF" (word variations have been searched)
8. (heart or cardiac or myocardial) near/3 (failure or decompensation)
9. heart near/4 fail*
10. #1 or #2 or #3 or #4 or #5 or #6 or #7 or #8 or #9
11. MeSH descriptor: [Exercise] explode all trees
12. MeSH descriptor: [Running] explode all trees
13. MeSH descriptor [Walking] explode all trees
14. MeSH descriptor: [Swimming] explode all trees
15. MeSH descriptor: [Muscle Stretching Exercises] explode all trees
16. MeSH descriptor: [Leisure Activities] explode all trees
17. MeSH descriptor: [Motor Activity] this term only
18. MeSH discriptor: [Guideline Adherence] explode all trees
19. MeSH descriptor: [Patient Compliance] explode all trees
20. MeSH descriptor: [Physical and rehabilitation Medicine] explode all trees
21. MeSH descriptor: [Physical Fitness] explode all trees
22. MeSH descriptor: [Activities of Daily Living] explode all trees
23. MeSH descriptor: [Physical Education and Training] explode all trees
24. MeSH descriptor: [Physical Endurance] explode all trees
25. physical near/4 activ*
26. "exercise tolerance" (word variation has been explode)
27. "Aerobic exercise" (word variation has been explode)
28. "Endurance exercise" (word variation has been explode)
29. "Resistance exercise" (word variation has been explode)
30. "Leisure activities" (word variation has been explode)
31. "Daily physical activity" (word variation has been explode)
32. "Cardiac rehabilitation" (word variation has been explode)
33. "Exercise therapy" (word variation has been explode)
34. Exercis*

35. #11 or #12 or #13 or #14 or #15 or #16 or #17 or #18 or #19 or #20 or #21 or #22 or #23 or #24 or #25 or #26 or #27 or #28 or #29 or #30 or #31 or #32 or #33 or #34
36. “Behavio?r* change” (Word variations have been searched, search through All Text)
37. MeSH descriptor: [Rehabilitation] explode all trees
38. MeSH descriptor: [Patient Care] explode all trees
39. MeSH descriptor: [Self Care] explode all trees
40. “Intervention” (word variation has been explode)
41. MeSH descriptor: [Behavior Control] explode all trees
42. “Health education” (word variation has been explode)
43. “Health behavio?r change” (word variation has been explode)
44. “Counseling” (word variation has been explode)
45. 36 or #37 or #38 or #39 or #40 or #41 or #42 or #43 or #44
46. # 10 and #35
47. # 10 and #35 and #45

Appendix D. Sources of biases in a review and their definitions

Selection bias is defined as systematic differences between baseline characteristics of the groups that are compared, which is usually dealt with by performing randomised allocation of participants to trial groups.

Performance bias is defined as systematic differences between groups in the care that is provided, or in exposure to factors other than the interventions of interest. Effective blinding ensures that the compared groups receive a similar attention. Due to the nature of physical activity interventions, this bias is present in every trial.

Detection bias is defined as systematic differences between groups in how outcomes are determined. Blinded assessment of the outcome may reduce the risk that knowledge of which intervention was received, rather than the intervention itself, affects outcome measurement.

Attrition bias is defined as systematic differences between groups in withdrawals from a study. Withdrawals from the study lead to incomplete outcome data. There are two reasons for withdrawals or incomplete outcome data in clinical trials. Exclusions refer to situations in which some participants are omitted from reports of analyses, despite outcome data being available to the trialists. Attrition refers to situations in which outcome data are not available.

Outcome reporting bias is defined as systematic differences between reported and unreported findings. Reporting bias refers to the selective reporting of some results but not others in trial publications. Incomplete reporting of outcomes within published articles of randomised trials is common and associated with space constraints, lack of clinical importance, and lack of statistical significance (Chan & Altman, 2005). For the purposes of this review, the intended analysis reported in the study's protocol was accessed to detect this bias.

Appendix E. Intervention characteristics

Author , year	Intervention description	General Approach	BCTs	Intervention Intensity (Duration)	Facilitator	Mode of delivery	Theory Use	TCS total score
Barnason et al., 2003	Home communication intervention 'Health Buddy'	Remote monitoring and feedback	IHC ; NSR; PS;	47 sessions, daily 10-minute sessions (6 weeks)	Research Nurse	Home-based Telemonitoring ('Health Buddy')	Social Cognitive Theory (Bandura, 1997)	5
van den Berg-Emons et al., 2004	Aerobic exercise training	Exercise programme	AP; BP/R; GS (B);	24 sessions, 60-minute sessions twice a week (12 weeks)	Not reported	Centre-based group exercise training	None	0
Bowie et al., 2014	Individually tailored e-health intervention 'Health Buddy'	Remote monitoring and feedback	IHC; SMB; SMOB	364 sessions, daily 10-minute session (52 weeks)	HF- Specialist Nurse; Nurse Assistant	Home-based Telemonitoring ('Health Buddy')	None	0

Brodie et al., 2005	Motivational Interviewing	MI	GT; IHC; PS; SC; SMB; SS(E); SS(U);	8 sessions, Weekly 60- minute sessions (8 weeks)	Researcher without clinical qualification	Home-based individual sessions	Motivational interviewing (Miller 1983)	2
	Motivational interviewing + education		GT; PS; SC; SMB; SS(E); SS(U)	8 sessions, weekly 60- minute sessions (8 weeks)	HF-specialist nurse; Researcher without clinical qualification	Home-based individual sessions + Usual care package	Motivational interviewing (Miller 1983)	2
Collins et al., 2004	Aerobic exercise training	Exercise programme	AOE; AP; BP/R; GS(B); GT; IHPB; RP/C	120 sessions, 50-minute sessions 5 days a week (24 weeks)	Exercise Physiologist or Nurse	Centre-based group exercise training	None	0
Corvera-Tindel et al., 2004a	Home walking exercise programme	Exercise programme	BP/R; GS(B); GT; MBbOwF; MOBwF; SMB	60 sessions, 60-minutes 5 days a week (12 weeks)	Nurse	Home-based, Supervised	None	0

Cowie et al., 2011	Hospital-based aerobic exercise training	Exercise programme	Intervention 1: AP; BP/R; DB; GS(B); GT; IHC; IHPB; RBG; SMB; SMOB;	16 sessions, 60-minutes sessions twice a week (8 weeks)	Exercise Instructor	Centre-based individual exercise training	None	0
	Home-based exercise training		Intervention 2: AP; BP/R ; DB; GS(B); GT; GTB: IHC; IHPB: SMOB;	16 sessions, 30-minute sessions twice a week (8 weeks)	Physiotherapist	Home-based, individual (DVD) exercise training	None	0

Duncan et al., 2003	Aerobic exercise training + adherence facilitation intervention	Exercise and Behaviour Change	Phase 1: AP; BC; BP/R; DB; GS(B); GTB; Phase 2: AP; BC; BP/R; FB; GS(B); GTB; SMB.	36 sessions, 50-minute sessions 3 times a week (24 weeks)	Cardiac Rehabilitation (CR) Staff	Centre-based group exercise training (Phase 1) home-based Individual exercise training (Phase 2)	Social Cognitive Theory (Bandura, 1997)	3

HF-ACTION (O'Connor et al., 2009)	Aerobic exercise training + Exercise adherence facilitation intervention	Exercise and Behaviour Change	AOE; AP; BP/R; CS; GS(B); GT; GTB; IHC; IHPB; PC; SMB; SMOB; SS(E); MBbOwF; SS(P); SS(U)	72 sessions, 3 sessions of unspecified duration a week (24 weeks)	Physiotherapist	Centre-based group exercise training	Transtheoretical model of Change (Prochaska & DiClemente, 1983); Motivational Interviewing	7
Jolly et al., 2009	Aerobic and resistance exercise training	Exercise programme	AP; BC; BP/R; DB; GS(B); GT; IHC; IHPB SMB; SS(U)	(i) 3 supervised exercise sessions; (ii) 3 home visits; (iii) 3 telephone sessions; (iv) 120 sessions, 30-minute self-applied sessions 5 times a week (24 weeks)	PA Instructor	Home-based, individual exercise training	None	0

Koelling et al., 2005	Educational session		CS; GS(B); IA; IHC; IHPB;	One 60-minute session	Nurse Educator	Centre-based individual session	None	0
Smeulders et al., 2006; 2009	Chronic disease self-management programme	Chronic disease self-management programme	AP; BC; BE; BP/R; D; DB; FB; IHC; ISRM; PS; R; RNE; SS(U); ST	6 sessions, 150-minute session once a week (6 weeks)	Lay leader (HF patient); HF-Specialist Nurse	Centre-based group exercise training and classes	Social Cognitive Theory (Bandura, 1997)	8
Tomita et al., 2008	Multidisciplinary Internet-based programme on management of HF	Remote monitoring and feedback	FB; IHC; IHPB; SMB	42 sessions, 10-minute sessions 5 times a month (52 weeks)	Self-applied (Website)	Home-based, individual sessions (Website)	Transtheoretical model of Change (Prochaska & DiClemente, 1983); Social Support Theory; Mass	2

							Communication Theory	
Willenheimer et al 2001	Aerobic exercise training	Exercise programme	AP; BP/R; DB; GS(B); GT; IHPB	41 session: two 15-minute sessions a week (7 weeks); 45-minute 3 sessions a week (9 weeks)	Physiotherapist	Centre-based, Group exercise training	None	0
Witham et al., 2005	Seated aerobic exercise training followed by seated resistance exercise training	Exercise programme	BP/R; GS(B); GT; GTB; IHC; MOBwF; SMB; SS(U)	17-20 sessions, 20-minute session twice a week (12 weeks)	Physiotherapist	Group, Centre-based exercise training (supervised and home settings) Followed by home self-monitoring, self-monitoring and goal setting.	None	0

Yeh et al., 2011	Exercise training (Tai Chi Mind-Body movement)	Exercise programme	AP; BC; BP/R; DB; GS(B); IHPB; SMB	Group sessions: 60-minute sessions twice a week; home sessions: 35-minute sessions three times a week (12 weeks)	Exercise Instructor	Centre-based, group exercise training	None	0

Note: AOE – 12.5 . Adding objects to the environment; AP – 1.4. Action planning; BC –12.6. Body changes; BE – 4.4. Behavioural experiments; BP/R – 8.1. Behavioural practice/rehearsal; CS – 9.2. Credible source; D – 12.4. Distraction; DB – 6.1. Demonstration of the behaviour; FB – 2.2. Feedback on behaviour; GS(B) – 1.1. Goal setting (behaviour); GT – 8.7. Graded tasks; GTB – 8.6. Generalisation of target behaviour; IA – 4.2. Information about antecedents; IHC – 5.1 Information about health consequences; IHPB – 4.1. Instruction on how to perform the behaviour; ISRM – 13.1. Identification of self as role model; MBbOwF - 2.5. Monitoring of behaviour by others without feedback; MOBwF – 2.5. Monitoring of outcomes of behaviour without feedback; NSR – 10.3. Non-specific reward; PC – 7.1. Prompts/cues; PS – 1.2. Problem solving; R – 4.3. Reattribution; RBG – 1.5. Review behaviour goal(s); RNE –11.2. Reduce negative emotions; RP/C – 7.3. Reduce prompts cues; SC – 6.2. Social comparison; SMB – 2.3. Self-monitoring of behaviour; SMOB – 2.4. Self-monitoring of outcome(s) of behaviour; SS(E) – 3.3. Social support (emotional); SS(P) –3.2. Social support (practical); SS(U) – 3.1. Social support (unspecified); ST – 15.4. Self-talk.

Appendix F. Identified BCTs and their definitions. Adopted from BCT Taxonomy (v1): 93 hierarchically clustered techniques.

Name of BCT	Definition of BCT as described in BCTTv1
1. Adding objects to the environment (12.5)	Add objects to the environment in order to facilitate performance of the behaviour.
2. Action planning (1.4)	Prompt detailed planning of performance of the behavior (must include at least one of context, frequency, duration and intensity). Context may be environmental (physical or social) or internal (physical, emotional or cognitive). Prompt planning the performance of a particular physical activity (e.g. running) at a particular time (e.g. before work) on certain days of the week.
3. Body changes (12.6)	Alter body structure, functioning or support directly to facilitate behavior change; Prompt strength training, relaxation training or provide assistive aids (e.g. a hearing aid).
4. Behavioural practice/rehearsal (8.1)	Prompt practice or rehearsal of the performance of the behavior one or more times in a context or at a time when the performance may not be necessary, in order to increase habit and skill.
5. Credible source (9.2)	Present verbal or visual communication from a credible source in favour of or against the behavior. Note: code this BCT if the source is generally agreed on as credible e.g., health professionals, celebrities or words used to indicate expertise or leader in the field and if the communication has the aim of persuading.
6. Demonstration of the behaviour (6.1)	Provide an observable sample of the performance of the behaviour, directly in person or indirectly e.g. via film, pictures, for the person to aspire to or imitate (includes 'Modelling'). Note: if advised to practice, also code, 8.1, Behavioural practice and rehearsal; If provided with instructions on how to perform, also code 4.1, Instruction on how to perform the behaviour.
7. Feedback on behaviour (2.2)	Monitor and provide informative or evaluative feedback on performance of the behavior (e.g. form, frequency, duration, intensity); Note: if Biofeedback, code only 2.6, Biofeedback and not 2.2, Feedback on behavior; if feedback is on outcome(s) of behavior, code 2.7, Feedback on outcome(s) of behavior; if there is no clear evidence that feedback was given, code 2.1, Monitoring of behavior by others without feedback; if feedback on behaviour is evaluative e.g. praise, also code 10.4, Social reward; Inform the person of how many steps

	they walked each day (as recorded on a pedometer) or how many calories they ate each day (based on a food consumption questionnaire).
8. Goal setting (behaviour) (1.1)	Set or agree on a goal defined in terms of the behavior to be achieved; Note: only code goal-setting if there is sufficient evidence that goal set as part of intervention; if goal unspecified or a behavioral outcome, code 1.3, Goal setting (outcome); if the goal defines a specific context, frequency, duration or intensity for the behavior, also code 1.4, Action planning; Agree on a daily walking goal (e.g. 3 miles) with the person and reach agreement about the goal.
9. Graded tasks (8.7)	Set easy-to-perform tasks, making them increasingly difficult, but achievable, until behavior is performed; Ask the person to walk for 100 yards a day for the first week, then half a mile a day after they have successfully achieved 100 yards, then two miles a day after they have successfully achieved one mile.
10. Generalisation of target behaviour (8.6)	Advise to perform the wanted behaviour, which is already performed in a particular situation, in another situation, Advise to repeat toning exercises learned in the gym when at home.
11. Information about health consequences (5.1)	Provide information (e.g. written, verbal, visual) about health consequences of performing the behavior; Note: consequences can be for any target, not just the recipient(s) of the intervention; emphasising importance of consequences is not sufficient; if information about emotional consequences, code 5.6, Information about emotional consequences; if about social, environmental or unspecified consequences code 5.3, Information about social and environmental consequences.
12. Instruction on how to perform the behaviour (4.1)	Advise or agree on how to perform the behavior (includes ‘Skills training’); Note: when the person attends classes such as exercise or cookery, code 4.1, Instruction on how to perform the behavior, 8.1, Behavioral practice/rehearsal and 6.1, Demonstration of the behaviour.
13. Monitoring of behaviour by others without feedback (2.1)	Observe or record behavior with the person’s knowledge as part of a behavior change strategy; Note: if monitoring is part of a data collection procedure rather than a strategy aimed at changing behavior, do not code; if feedback given, code only 2.2, Feedback on behavior, and not 2.1, Monitoring of behavior by others without feedback; if monitoring outcome(s) code 2.5, Monitoring outcome(s) of behavior by others without feedback; if self-monitoring behavior, code 2.3, Self-monitoring of behaviour.
14. Monitoring of outcomes of behaviour without feedback (2.5)	Observe or record outcomes of behavior with the person’s knowledge as part of a behavior change strategy; Note: if monitoring is part of a data collection procedure rather than a strategy aimed at changing behavior, do not code; if feedback given,

	code only 2.7, Feedback on outcome(s) of behavior; if monitoring behavior code 2.1, Monitoring of behavior by others without feedback; if self-monitoring outcome(s), code 2.4, Self-monitoring of outcome(s) of behavior.
15. Problem solving (1.2)	Analyse , or prompt the person to analyse, factors influencing the behavior and generate or select strategies that include overcoming barriers and/or increasing facilitators (includes ‘Relapse Prevention’ and ‘Coping Planning’); Note: barrier identification without solutions is not sufficient. If the BCT does not include analysing the behavioral problem, consider 12.3, Avoidance/changing exposure to cues for the behavior, 12.1, Restructuring the physical environment, 12.2, Restructuring the social environment, or 11.2, Reduce negative emotions; Prompt the patient to identify barriers preventing them from starting a new exercise regime e.g., lack of motivation, and discuss ways in which they could help overcome them e.g., going to the gym with a buddy.
16. Social comparison (6.2)	Draw attention to others’ performance to allow comparison with the persons own performance Note: being in a group setting does not necessarily mean that social comparison is actually taking place.
17. Self-monitoring of behaviour (2.3)	Establish a method for the person to monitor and record their behavior(s) as part of a behavior change strategy; Give patient a pedometer and a form for recording daily total number of steps.
18. Self-monitoring of outcome(s) of behaviour (2.4)	Establish a method for the person to monitor and record the outcome(s) of their behavior as part of a behavior change strategy; Note: if monitoring is part of a data collection procedure rather than a strategy aimed at changing behavior, do not code ; if monitoring behavior, code 2.3, Self-monitoring of behavior; if monitoring is by someone else (without feedback), code 2.5, Monitoring outcome(s) of behavior by others without feedback.
19. Social support (emotional) (3.3)	Advise on, arrange, or provide emotional social support (e.g. from friends, relatives, colleagues, ‘buddies’ or staff) for performance of the behavior;Note: if practical, code 3.2, Social support (practical); if unspecified, code 3.1, Social support (unspecified).
20. Social support (unspecified) (3.1)	Advise on, arrange or provide social support (e.g. from friends, relatives, colleagues,’ buddies’ or staff) or non-contingent praise or reward for performance of the behavior. It includes encouragement and counselling, but only when it is directed at the behavior; Note: attending a group class and/or mention of ‘follow-up’ does not necessarily apply this BCT, support must be explicitly mentioned; if practical, code 3.2, Social support (practical); if emotional, code 3.3, Social support (emotional) (includes ‘Motivational interviewing’ and ‘Cognitive Behavioral Therapy’).

Appendix G. Definitions and assessment of physical activity across included RCTs

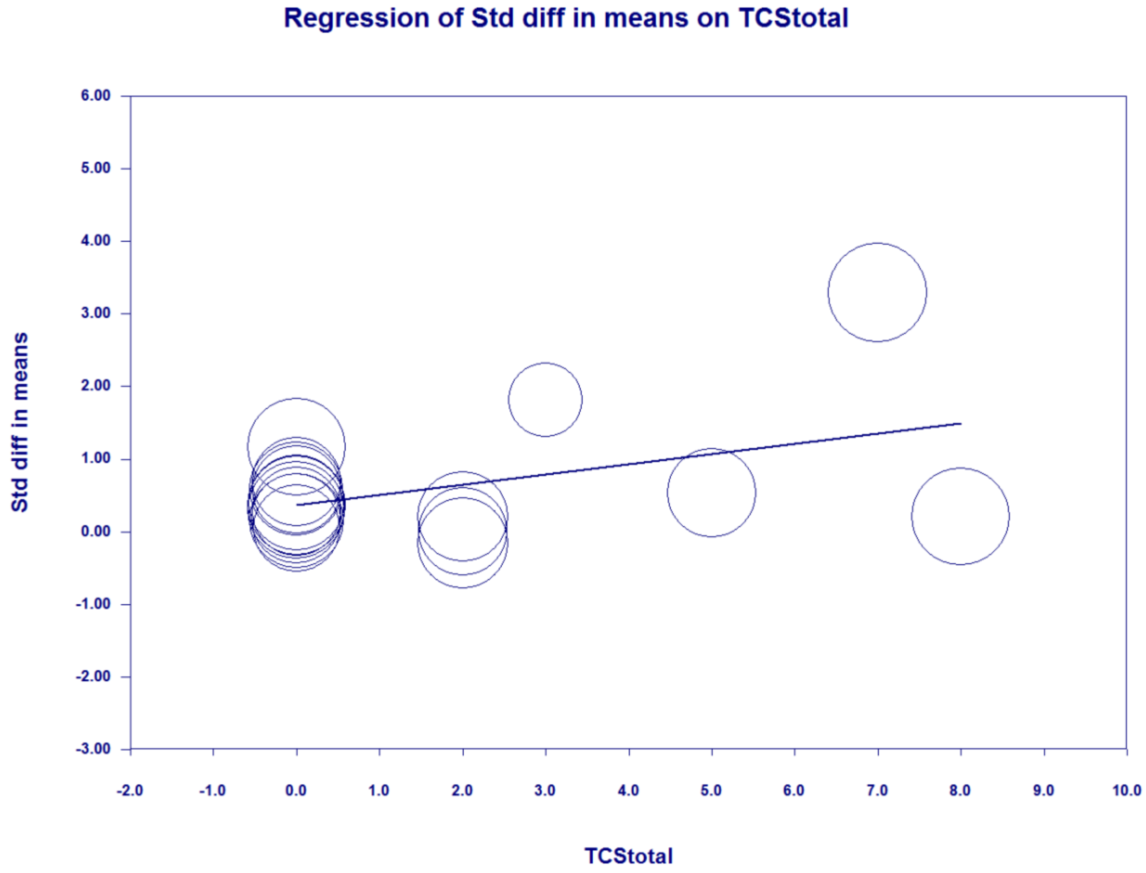
Mode of physical activity	**Definition formulated using a description provided by the authors of the included trials**	**Assessment method**
Exercise	Conceptualised as a self-care behaviour: a behaviour performed to manage HF	Barnason et al. (2003): self-report: Physical Activity Questionnaire (Schuster et al., 1995) Boyne et al. (2014): self-report: HF Compliance Scale (Jaarsma, Strömberg, Mårtensson, & Dracup, 2003) Koelling et al. (2003): (self-report: HF Compliance Scale (Jaarsma et al., 2003))
	Unspecified exercise	Duncan et al. (2003): self-report (non-specified diary) Jolly et al. (2009) (self-report: (Godin & Shephard, 1985)
Daily activity	Physical activity performed as part of daily life. Measured on a daily basis.	Berg-Emons et al. (2004): accelerometer Witham et al., (2005): accelerometer Cowie et al., (2011): accelerometer Collins et al. (2004): self-report (unspecified diary)
Habitual activity	A summary of regularly performed physical activity at a particular intensity over a period of time.	Willenheimer et al. (2001) Self-report (The total physical activity score calculated using the following formula: Time spent on each activity per week x intensity2/100)
General physical activity	The total score summarises activity of different modes (sitting, walking, stair	Brodie et al. (2008): self-report (Booth et al., 1996)

	climbing, leisure-time activities). Measured retrospectively at one time point.	HF-ACTION (O'Connor et al., 2009): self-report (unspecified) Yeh et al. (2011) (CHAMPS; Stewart 2001)
Walking		Corvera-Tindel et al. (2004a) (pedometer) Smeulders et al. (2009): self-report (PA scale Lorig 1996) Tomita et al. (2008): self-report (unspecified)

Appendix H. Association between efficacy (SMD) and sample characteristics.

Sample characteristic	Coefficient	SE	CI (lower bound)	CI (upper bound)	Z-value	p-value (two-tailed)	Proportion of variance explained (R^2)
Intercept (Age meta-regression model)	4.90	1.92	1.13	8.67	2.55	0.01	
Age	-0.06	0.03	-0.12	-0.01	-2.25	0.02	0.25
Intercept (Average LVEF % meta-regression model)	0.49	3.78	-6.92	7.90	0.13	0.90	
Average LVEF (%)	0.00	0.11	-0.21	0.22	0.02	0.98	0.00
Intercept (NYHA class I meta-regression model)	0.66	0.61	-0.54	1.86	1.07	0.28	
Proportion of participants within NYHA class I	-0.02	0.08	-0.18	0.14	-0.27	0.79	0.00
Intercept (NYHA class II meta-regression model)	-0.39	1.61	-3.55	2.78	-0.24	0.81	
Proportion of participants within NYHA class II	0.02	0.03	-0.04	0.08	0.63	0.53	0.14
Intercept (NYHA class III meta-regression model)	0.93	1.46	-1.93	3.80	0.64	0.52	
Proportion of participants in NYHA III	-0.01	0.03	-0.07	0.06	-0.26	0.79	0.00
Intercept (NYHA class IV meta-regression model)	0.58	0.52	-0.44	1.61	1.12	0.26	
Proportion of participants in NYHA IV	-0.03	0.10	-0.24	0.17	-0.34	0.74	0.00

Appendix I. A scatter plot demonstrating regression of the SMD on TCS total score.



Appendix J. The empirical evidence (Jaarsma et al., 2013) used to obtain the hyperprior probability distribution for physical activity in HF.

Country/Continent	Total N assessed	Pr (PA = 0)	N (PA = 0)	N (PA = 1)	Pr (PA = 1)	Variance
Asia	896	0.58	517	379.36	0.42	0.005
Australia	715	0.48	342	373.23	0.52	0.004
North America	765	0.59	451	313.78	0.41	0.004
Germany	225	0.38	86	138.6	0.62	0.003
Italy	819	0.63	518	301.14	0.37	0.009
Spain	963	0.62	597	365.94	0.38	0.01
Netherlands	967	0.44	425	541.52	0.56	0.009
Sweden	402	0.67	268	134.23	0.33	0.009
Serbia	106	0.51	54	51.94	0.49	0.01
US North East	280	0.43	120	159.6	0.57	0.009
US South East	351	0.66	232	119.34	0.34	0.009
US Mexican South West	134	0.74	99	34.84	0.26	0.01
Brazil	106	0.89	94	11.66	0.11	0.01
Japan	127	0.53	67	59.69	0.47	0.02
Israel	42	0.57	24	18.06	0.43	0.02
Vietnam	126	0.41	52	74.34	0.59	0.02
Hong Kong	167	0.83	139	28.39	0.17	0.02
Thailand	400	0.53	212	188	0.47	0.02
Taiwan	34	0.68	23	10.88	0.32	0.02
Total	7625	0.57	4320	3305	0.43	0.02

Appendix K. Expert elicitation task

The review aims to summarise both qualitative and quantitative evidence regarding barriers and enablers to physical activity in heart failure.

Please read the research articles attached and choose Theoretical Domains (Cane et al., 2012) that are suggested to be relevant to physical activity in heart failure according to the findings of each article:

Please take a minute to consider the research findings and what implications they would have if they were describing a number of **hypothetical** heart failure patients.

Below are short scenarios describing 16 hypothetical heart failure patients (*Patient A to Patient X*). Each scenario is presented on a separate page. For each scenario, basing on the findings of the papers you have read (Tierney et al., 2011a; Tierney et al., 2011b; Pihl et al., 2011) and **nothing else** please respond to two questions:

a) Do you think the patient engages in physical activity at a recommended level (*walks every day and performs at least 10 minutes of aerobic exercise, such as brisk walking once a week*)?

b) how certain are you in your answer?

Please read each scenario **one at a time**. For each scenario, respond to the questions before you move on to the next scenario. Please **do not compare scenarios** to each other in making decisions about your responses and consider each scenario in isolation.

1. Patient A is 54 years old; has diabetes and arthritis; is confident in one's ability to engage in physical activity but perceives low level of social support to do so.

After considering the qualitative evidence, do you think Patient A engages in physical activity at a recommended level?

☐ YES ☐ NO

How certain are you in your answer?

☐ 0% : Absolutely uncertain
☐ 10% : Very uncertain
☐ 20% : Largely uncertain
☐ 30% : Mostly uncertain
☐ 40% : Somewhat Uncertain
☐ 50% : Cannot tell
☐ 60% : Somewhat Certain
☐ 70% : Mostly certain
☐ 80% : Largely certain
☐ 90% : Very certain
☐ 100% : Absolutely certain

2. Patient B is 76 years old; has diabetes and arthritis; lacks the confidence in one’s ability to engage in physical activity, but whose friends and family encourage to be active.

After considering the qualitative evidence, do you think Patient B engages in physical activity at a recommended level?

☐ YES ☐ NO

How certain are you in your answer?

☐ 0% : Absolutely uncertain
☐ 10% : Very uncertain
☐ 20% : Largely uncertain
☐ 30% : Mostly uncertain
☐ 40% : Somewhat Uncertain
☐ 50% : Cannot tell
☐ 60% : Somewhat Certain
☐ 70% : Mostly certain
☐ 80% : Largely certain
☐ 90% : Very certain
☐ 100% : Absolutely certain

3. Patient C is 54 years old; does not have any other illnesses; is confident in one's ability to engage in physical activity but perceives low level of social support to do so.

After considering the qualitative evidence, do you think Patient C engages in physical activity at a recommended level?

☐ YES ☐ NO

How certain are you in your answer?

- ☐ 0% : Absolutely uncertain
- ☐ 10% : Very uncertain
- ☐ 20% : Largely uncertain
- ☐ 30% : Mostly uncertain
- ☐ 40% : Somewhat Uncertain
- ☐ 50% : Cannot tell
- ☐ 60% : Somewhat Certain
- ☐ 70% : Mostly certain
- ☐ 80% : Largely certain
- ☐ 90% : Very certain
- ☐ 100% : Absolutely certain

4. Patient D is 76 years old; has diabetes and arthritis; is confident in one's ability to engage in physical activity but perceives low level of social support to do so.

Do you think Patient D engages in physical activity at a recommended level?

☐ YES ☐ NO

How certain are you in your answer?

☐ 0% : Absolutely uncertain
☐ 10% : Very uncertain
☐ 20% : Largely uncertain
☐ 30% : Mostly uncertain
☐ 40% : Somewhat Uncertain
☐ 50% : Cannot tell
☐ 60% : Somewhat Certain
☐ 70% : Mostly certain
☐ 80% : Largely certain
☐ 90% : Very certain
☐ 100% : Absolutely certain

5. Patient E is 54 years old; has diabetes and arthritis; lacks the confidence in one's ability to engage in physical activity, but whose friends and family encourage to be active.

After considering the qualitative evidence, do you think Patient E engages in physical activity at a recommended level?

☐ YES ☐ NO

How certain are you in your answer?

☐ 0% : Absolutely uncertain
☐ 10% : Very uncertain
☐ 20% : Largely uncertain
☐ 30% : Mostly uncertain
☐ 40% : Somewhat Uncertain
☐ 50% : Cannot tell
☐ 60% : Somewhat Certain
☐ 70% : Mostly certain
☐ 80% : Largely certain
☐ 90% : Very certain

☐ 100%   : Absolutely certain

6. Patient F is 76 years old; does not have any other illnesses; lacks the confidence in one's ability to engage in physical activity but perceives low level of social support in being physically active.

After considering the qualitative evidence, do you think Patient F engages in physical activity at a recommended level?

☐ YES ☐ NO

How certain are you in your answer?

☐ 0% : Absolutely uncertain
☐ 10% : Very uncertain
☐ 20% : Largely uncertain
☐ 30% : Mostly uncertain
☐ 40% : Somewhat Uncertain
☐ 50% : Cannot tell
☐ 60% : Somewhat Certain
☐ 70% : Mostly certain
☐ 80% : Largely certain
☐ 90% : Very certain
☐ 100% : Absolutely certain

7. Patient G is 76 years old; has diabetes and arthritis; lacks the confidence in one's ability to engage in physical activity and perceives low level of social support to do so.

After considering the qualitative evidence, do you think Patient G engages in physical activity at a recommended level?

☐ YES ☐ NO

How certain are you in your answer?

☐ 0% : Absolutely uncertain
☐ 10% : Very uncertain
☐ 20% : Largely uncertain
☐ 30% : Mostly uncertain
☐ 40% : Somewhat Uncertain
☐ 50% : Cannot tell
☐ 60% : Somewhat Certain
☐ 70% : Mostly certain
☐ 80% : Largely certain
☐ 90% : Very certain
☐ 100% : Absolutely certain

8. Patient H is 54 years old; does not have any illnesses; lacks the confidence in one's ability to engage in physical activity and perceives low level of social support to do so.

After considering the qualitative evidence, do you think Patient H engages in physical activity at a recommended level?

☐ YES ☐ NO

How certain are you in your answer?

☐ 0% : Absolutely uncertain
☐ 10% : Very uncertain
☐ 20% : Largely uncertain
☐ 30% : Mostly uncertain
☐ 40% : Somewhat Uncertain
☐ 50% : Cannot tell
☐ 60% : Somewhat Certain
☐ 70% : Mostly certain
☐ 80% : Largely certain
☐ 90% : Very certain
☐ 100% : Absolutely certain

9. Patient I is 76 years old; does not have any other illnesses; lacks the confidence in one’s ability to engage in physical activity, but whose friends and family encourage to be active.

After considering the qualitative evidence, do you think Patient I engages in physical activity at a recommended level?

☐ YES ☐ NO

How certain are you in your answer?

☐ 0% : Absolutely uncertain
☐ 10% : Very uncertain
☐ 20% : Largely uncertain
☐ 30% : Mostly uncertain
☐ 40% : Somewhat Uncertain
☐ 50% : Cannot tell
☐ 60% : Somewhat Certain
☐ 70% : Mostly certain
☐ 80% : Largely certain
☐ 90% : Very certain
☐ 100% : Absolutely certain

10. Patient J is 54 years old; has diabetes and arthritis; lacks the confidence in one's ability to engage in physical activity and perceives low level of social support to do so.

After considering the qualitative evidence, do you think Patient J engages in physical activity at a recommended level?

☐ YES ☐ NO

How certain are you in your answer?

☐ 0% : Absolutely uncertain
☐ 10% : Very uncertain
☐ 20% : Largely uncertain
☐ 30% : Mostly uncertain
☐ 40% : Somewhat Uncertain
☐ 50% : Cannot tell
☐ 60% : Somewhat Certain
☐ 70% : Mostly certain
☐ 80% : Largely certain
☐ 90% : Very certain
☐ 100% : Absolutely certain

11. Patient K is 76 years old; has diabetes and arthritis; is confident in one's ability to engage in physical activity, and whose friends and family encourage to be physically active.

After considering the qualitative evidence, do you think Patient K engages in physical activity at a recommended level?

☐ YES ☐ NO

How certain are you in your answer?

☐ 0% : Absolutely uncertain
☐ 10% : Very uncertain
☐ 20% : Largely uncertain
☐ 30% : Mostly uncertain
☐ 40% : Somewhat Uncertain
☐ 50% : Cannot tell
☐ 60% : Somewhat Certain
☐ 70% : Mostly certain
☐ 80% : Largely certain
☐ 90% : Very certain
☐ 100% : Absolutely certain

12. Patient L is 76 years old, does not have any other illnesses; is confident in one's ability to engage in physical activity, but perceives low level of social support to do so.

After considering the qualitative evidence, do you think Patient L engages in physical activity at a recommended level?

☐ YES ☐ NO

How certain are you in your answer?

☐ 0% : Absolutely uncertain
☐ 10% : Very uncertain
☐ 20% : Largely uncertain
☐ 30% : Mostly uncertain
☐ 40% : Somewhat Uncertain
☐ 50% : Cannot tell
☐ 60% : Somewhat Certain
☐ 70% : Mostly certain
☐ 80% : Largely certain
☐ 90% : Very certain
☐ 100% : Absolutely certain

13. Patient M is 54 years old; has diabetes and arthritis; is confident in one's ability to engage in physical activity, and whose friends and family encourage to be physically active.

After considering the qualitative evidence, do you think Patient M engages in physical activity at a recommended level?

☐ YES ☐ NO

How certain are you in your answer?

☐ 0% : Absolutely uncertain
☐ 10% : Very uncertain
☐ 20% : Largely uncertain
☐ 30% : Mostly uncertain
☐ 40% : Somewhat Uncertain
☐ 50% : Cannot tell
☐ 60% : Somewhat Certain
☐ 70% : Mostly certain
☐ 80% : Largely certain
☐ 90% : Very certain
☐ 100% : Absolutely certain

14. Patient N is 54 years old; does not have any other illnesses; is confident in one's ability to engage in physical activity, and whose friends and family encourage to be physically active.

After considering the qualitative evidence, do you think Patient N engages in physical activity at a recommended level?

☐ YES ☐ NO

How certain are you in your answer?

☐ 0% : Absolutely uncertain
☐ 10% : Very uncertain
☐ 20% : Largely uncertain
☐ 30% : Mostly uncertain
☐ 40% : Somewhat Uncertain
☐ 50% : Cannot tell
☐ 60% : Somewhat Certain
☐ 70% : Mostly certain
☐ 80% : Largely certain
☐ 90% : Very certain
☐ 100% : Absolutely certain

15. Patient O is 76 years old; does not have any other illnesses; is confident in one's ability to engage in physical activity, and whose friends and family encourage to be physically active.

After considering the qualitative evidence, do you think Patient O engages in physical activity at a recommended level?

☐ YES ☐ NO

How certain are you in your answer?

☐ 0% : Absolutely uncertain
☐ 10% : Very uncertain
☐ 20% : Largely uncertain
☐ 30% : Mostly uncertain
☐ 40% : Somewhat Uncertain
☐ 50% : Cannot tell
☐ 60% : Somewhat Certain
☐ 70% : Mostly certain
☐ 80% : Largely certain

☐ 90% : Very certain
☐ 100% : Absolutely certain

16. Patient P is 54 years old; does not have any other illnesses; lacks the confidence in one's ability to engage in physical activity, but whose friends and family encourage to be physically active.

After considering the qualitative evidence, do you think Patient P engages in physical activity at a recommended level?

☐ YES ☐ NO

How certain are you in your answer?

☐ 0% : Absolutely uncertain
☐ 10% : Very uncertain
☐ 20% : Largely uncertain
☐ 30% : Mostly uncertain
☐ 40% : Somewhat Uncertain
☐ 50% : Cannot tell
☐ 60% : Somewhat Certain
☐ 70% : Mostly certain
☐ 80% : Largely certain
☐ 90% : Very certain
☐ 100% : Absolutely certain

17. Patient Q is 76 years old, his functioning and somatic state declined in the past few years, and he experiences moderate to severe HF symptoms.

After considering the qualitative evidence, do you think Patient Q engages in physical activity at a recommended level?

☐ YES ☐ NO

How certain are you in your answer?

☐ 0% : Absolutely uncertain
☐ 10% : Very uncertain
☐ 20% : Largely uncertain
☐ 30% : Mostly uncertain
☐ 40% : Somewhat Uncertain
☐ 50% : Cannot tell
☐ 60% : Somewhat Certain
☐ 70% : Mostly certain
☐ 80% : Largely certain
☐ 90% : Very certain
☐ 100% : Absolutely certain

18. Patient R is 54 years old, did not experience a decline in his physical functioning (changing soma), and does not show any HF symptoms.

After considering the qualitative evidence, do you think Patient R engages in physical activity at a recommended level?

☐ YES ☐ NO

How certain are you in your answer?

☐ 0% : Absolutely uncertain
☐ 10% : Very uncertain
☐ 20% : Largely uncertain
☐ 30% : Mostly uncertain
☐ 40% : Somewhat Uncertain
☐ 50% : Cannot tell
☐ 60% : Somewhat Certain
☐ 70% : Mostly certain
☐ 80% : Largely certain
☐ 90% : Very certain
☐ 100% : Absolutely certain

19. Patient S is 54 years old, his functioning and somatic state declined in the past few years, and he experiences moderate to severe HF symptoms.

After considering the qualitative evidence, do you think Patient S engages in physical activity at a recommended level?

☐ YES ☐ NO

How certain are you in your answer?

☐ 0% : Absolutely uncertain
☐ 10% : Very uncertain
☐ 20% : Largely uncertain
☐ 30% : Mostly uncertain
☐ 40% : Somewhat Uncertain
☐ 50% : Cannot tell
☐ 60% : Somewhat Certain
☐ 70% : Mostly certain
☐ 80% : Largely certain
☐ 90% : Very certain
☐ 100% : Absolutely certain

20. Patient T is 54 years old, did not experience a decline in his physical functioning (changing soma), but experiences moderate to severe HF symptoms.

After considering the qualitative evidence, do you think Patient T engages in physical activity at a recommended level?

☐ YES ☐ NO

How certain are you in your answer?

☐ 0% : Absolutely uncertain
☐ 10% : Very uncertain
☐ 20% : Largely uncertain
☐ 30% : Mostly uncertain
☐ 40% : Somewhat Uncertain
☐ 50% : Cannot tell
☐ 60% : Somewhat Certain
☐ 70% : Mostly certain
☐ 80% : Largely certain
☐ 90% : Very certain
☐ 100% : Absolutely certain

21. Patient U is 76 years old, did not experience a decline in his physical functioning (changing soma), and does not show any HF symptoms.

After considering the qualitative evidence, do you think Patient U engages in physical activity at a recommended level?

☐ YES ☐ NO

How certain are you in your answer?

☐ 0% : Absolutely uncertain
☐ 10% : Very uncertain
☐ 20% : Largely uncertain
☐ 30% : Mostly uncertain
☐ 40% : Somewhat Uncertain
☐ 50% : Cannot tell
☐ 60% : Somewhat Certain
☐ 70% : Mostly certain
☐ 80% : Largely certain
☐ 90% : Very certain
☐ 100% : Absolutely certain

22. Patient V is 76 years old, did not experience a decline in his physical functioning (changing soma), but experiences moderate to severe HF symptoms.

After considering the qualitative evidence, do you think Patient V engages in physical activity at a recommended level?

☐ YES ☐ NO

How certain are you in your answer?

☐ 0% : Absolutely uncertain
☐ 10% : Very uncertain
☐ 20% : Largely uncertain
☐ 30% : Mostly uncertain
☐ 40% : Somewhat Uncertain
☐ 50% : Cannot tell
☐ 60% : Somewhat Certain
☐ 70% : Mostly certain
☐ 80% : Largely certain
☐ 90% : Very certain
☐ 100% : Absolutely certain

23. Patient W is 54 years old, his functioning and somatic state declined in the past few years, but he does not show any HF symptoms.

After considering the qualitative evidence, do you think Patient W engages in physical activity at a recommended level?

☐ YES ☐ NO

How certain are you in your answer?

☐ 0% : Absolutely uncertain
☐ 10% : Very uncertain
☐ 20% : Largely uncertain
☐ 30% : Mostly uncertain
☐ 40% : Somewhat Uncertain
☐ 50% : Cannot tell
☐ 60% : Somewhat Certain
☐ 70% : Mostly certain
☐ 80% : Largely certain
☐ 90% : Very certain
☐ 100% : Absolutely certain

24. Patient X is 76 years old, his functioning and somatic state declined in the past few years, but he does not show any HF symptoms.

After considering the qualitative evidence, do you think Patient X engages in physical activity at a recommended level?

☐ YES ☐ NO

How certain are you in your answer?

☐ 0% : Absolutely uncertain
☐ 10% : Very uncertain
☐ 20% : Largely uncertain
☐ 30% : Mostly uncertain
☐ 40% : Somewhat Uncertain
☐ 50% : Cannot tell
☐ 60% : Somewhat Certain
☐ 70% : Mostly certain
☐ 80% : Largely certain
☐ 90% : Very certain
☐ 100% : Absolutely certain

Appendix L. Participant characteristics: a Bayesian meta-analysis.

Author, year		**Age,** Mean (SD)	**Male,** N (%)	**Diagnosis, years,** Mean (SD)	**BMI,** Mean (SD)	**LVEF, %** Mean (SD)	**NYHA I,** N (%)	**NYHA II,** N (%)	**NYHA III,** N (%)	**NYHA IV** N (%)
Alosco et al., 2012		69.81 (8.79)	60 (63.5)							
Andreae et al., 2019		70.7 (11)	130 (70)	<5 years: 141 (76)	28.7 (5.3)					
Chien et al., 2014		63.2 (11.5)	69 (62.2)		25.7 (4.93)	48.9 (16.4)	44 (39.7)	44 (39.6)	23 (20.7)	
Corvera-Tindel et al., 2004a			0							
Dontje et al., 2014		62 (14)	48 (71)		27.6 (4.8)	35 (15)	20.5 (30)	20.5 (30)	27 (40)	
Evangelista et al., 2003	*Male*	68.59	94 (67)					(42.7)	(35.4)	
	Female		-					(40)	(31.4)	

Evangelista et al., 2001	<60 y.old: 52(63.4%)	51 (62.2)	5.72 (5.99)		27.6 (11.6)				
Gad et al., 2018	66 (11)	21 (83)							
Garet et al., 2005	52.3 (11.2)	6 (15.3)		26.3 (4.5)	33.9 (4.8)				
Gallagher et al., 2011	72 (11)	220 (66)					21 (6)	170 (51)	139 (42)
Gonzalez et al., 2004	65.4 (10.8)	0			31 (12)	15 (5)	130 (45)	125 (45)	
Haedtke et al., 2017	67 (8.8)	46 (75)				14 (5)	20 (33)	37 (60)	4 (7)
Ho et al., 2014	81 [IQR: 75; 86][a]						5 (31)		
Oka	59.9 [IQR: 33;91][a]	35 (81.4)							
Jaarsma et al., 2000	72.9 (9)	77 (60)	9.9 (7)		35.9 (14)				36 (28)
Klompstra et al., 2015	70 (10)	73 (73)	2.75 (2.58)			4 (4)	32 (32)	55 (55)	18 (18)

Klompstra et al., 2018		67 (13)	95 (62)	3.08 [IQR:0.17;16][a]	28 [IQR: 19; 48]					
Kramer et al., 2017		70.2 (11)	18742 (70.7)							
Lee et al., 2017		62.15 (9.06)	93(80.2)	4.32 (4.97)		29.83 (7.44)	71 (61.2)	34 (29.3)	11 (9.5)	
Moreno-Soarez et al., 2020	*Exposed*	59.1 (10.8)	26 (81)	7.7 (7.5)		22.2 (9.2)		5 (31)		11 (69)
	Unexposed	58.3 (8.7)	26 (81)	5.9 (6.2)		25.3 (7.5)		6 (38)		10 (63)
Pihl			0							
Pozehl et al. 2018		60.4 (11.5)	224 (56)		34.9 (8.3)	39.4 (12.7)	14 (7.7)	101 (55.5)	65 (35.7)	2 (1.1)
Snipelisky et al.. 2017		69	44 (40)			63.9				
Tierney			0							
Tierney			0							

van der Wal et al., 2006	72 (11)	300.6 (60)	3.33[IQR:0.92; 6.58][a]		34 (24)	184 (38)	270 (56)	27 (6)
van der Wal et al., 2010	70 (11)	522.9 (63)			34 (14)			
Werhahn et al., 2019	46.3 (7.8)	0.6 (6)			26.5 (9.8)			
Witham et al., 2006	80.5 (5)	45.1 (55)		26.2 (4.5)		46 (56)	36 (43.90)	

Appendix M. AMSTAR 2 online evaluation form: barrier and enablers to physical activity in HF: a Bayesian meta-analysis

Barrier and Enablers to physical activity in HF: Bayesian Meta-analysis is a High-quality review

1. Did the research questions and inclusion criteria for the review include the components of PICO?	Yes Yes Yes Yes Yes Yes
2. Did the report of the review contain an explicit statement that the review methods were established prior to the conduct of the review and did the report justify any significant deviations from the protocol? Comment from the author: The protocol was not published online yet but is attached in Appendix X	Yes
3. Did the review authors explain their selection of the study designs for inclusion in the review? p. 111	Yes Yes
4. Did the review authors use a comprehensive literature search strategy? Comment from the author: The original search identified a large number of studies (11,678) due to the lack of restriction on the Intervention/Exposure search component within PIECOT. For quality consideration, and practical reasons the search was restricted to articles that were peer-reviewed and written in English, respectively.	Partial Yes Yes Yes Yes
5. Did the review authors perform study selection in duplicate?	Yes

6. Did the review authors perform data extraction in duplicate? Yes
Yes

7. Did the review authors provide a list of excluded studies and justify the exclusions? Partial Yes
Yes

Comment from the author: A list of articles that was screened in full text only

8. Did the review authors describe the included studies in adequate detail?

Comment from the author: p. 122

Yes
Yes
Yes
Yes
Yes
Yes

9. Did the review authors use a satisfactory technique for assessing the risk of bias (RoB) in individual studies that were included in the review?
RCT

NRSI Yes

Comment from the author: the studies were not RCTs and therefore alternative risk of bias tools were used. p 115-116

Yes
Yes
Yes
Yes

10. Did the review authors report on the sources of funding for the studies included in the review?	Yes Yes

11. If meta-analysis was performed did the review authors use appropriate methods for statistical combination of results?
RCT

NRSI	Yes
Comment from the author: the methods used for the synthesis of the findings including statistical analysis is reported on p. 117	Yes Yes Yes Yes Yes Yes Yes

12. If meta-analysis was performed, did the review authors assess the potential impact of RoB in individual studies on the results of the meta-analysis or other evidence synthesis?	**NRSI**
	Yes Yes

13. Did the review authors account for RoB in individual studies when interpreting/ discussing the results of the review?	**NRSI**
NRSI	Yes

Comment from the author:

Confounding: only unadjusted correlation coefficients were pooled. However, the prior for general physical activity is an alternative way to adjust for unknown confounding effects, further discussion is offered on p. 158.

Selection bias: only homogeneous samples were pooled. If the inclusion criteria for the individual study was different (p. and selection of the results from among multiple measurements

14. Did the review authors provide a satisfactory explanation for, and discussion of, any heterogeneity observed in the results of the review?	No
15. If they performed quantitative synthesis did the review authors carry out an adequate investigation of publication bias (small study bias) and discuss its likely impact on the results of the review?	Yes Yes
16. Did the review authors report any potential sources of conflict of interest, including any funding they received for conducting the review?	Yes Yes

Shea BJ, Reeves BC, Wells G, Thuku M, Hamel C, Moran J, Moher D, Tugwell P, Welch V, Kristjansson E, Henry DA. AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. BMJ. 2017 Sep 21;358:j4008.

Appendix N. Using mixed-methods research in understanding barriers and enablers to physical activity in HF

Study design

This study is conducted using a sequential exploratory mixed-methods approach, where the qualitative component precedes and informs the quantitative element (Creswell & Plano Clark, 2011). In Phase 1, semi-structured interviews to explore perceived barriers to and enablers of physical activity in HF will be conducted with a purposive sample of 16 participants. In Phase 2, a convenience sample of people attending HF outpatient clinics will be asked to complete a validated questionnaire on factors that may influence physical activity and to wear an accelerometer, which will attempt to measure the actual physical activity levels. The choice of the quantitative measures will be determined by the barriers and enablers identified in Phase 1.

The rationale for the choice of the design

It is appropriate to answer RQ1 using a qualitative approach, because of the exploratory nature of the question. RQ2 will examine the relationship between potential barriers to and enablers of physical activity and the levels of physical activity, and thus is most appropriately addressed by employing a quantitative approach. The close link between the research questions and the reliance of the quantitative phase on the findings of the qualitative phase suggested a mixed methods study as the most appropriate, specifically a sequential exploratory design (Creswell & Plano Clark, 2011). A sequential exploratory design is ideal for explorations of new phenomena. As there is little empirical understanding of factors and relations among them that may influence physical activity in HF, the sequential exploratory mixed-methods approach serves as the ideal design for this inquiry. Further rationale for the use of the mixed-methods approach and additional decisions concerning methodology, as well as the rationale for them will be clarified below, after outlining the philosophical stance being taken and the framework being utilised in this study.

Philosophical stance of the project

The main philosophical stances that have been traditionally juxtaposed in research are positivism/post-positivism and constructivism/interpretivism (Creswell & Plano Clark, 2011). The positivists suggest a singular reality that can be investigated using objective and value-free inquiry underpinning quantitative research methods. This is contrasted with the constructivists' stand point suggesting a concept of subjective reality, which is most appropriately investigated using qualitative research methods (Creswell & Plano Clark, 2011).

This project does not identify itself with either a positivist or constructivist stance and chooses pragmatism (Rossmann & Wilson, 1985) as a philosophical stance for the following reasons. Firstly, this approach strives to employ multiple world views in order to address a research problem in a useful and comprehensive way (Rossman & Wilson, 1985) which sits well with the objective of this project to provide a comprehensive account of factors that may influence physical activity in HF. Pragmatism enables the researchers to provide the participants' perspective using methods of investigation offered by the health psychology discipline and allows the combination of qualitative and quantitative methods effectively (Creswell & Plano Clark, 2011) to produce a more comprehensive understanding of factors that may influence physical activity in HF. Secondly, pragmatism is a problem-centred and practice-oriented approach to research (Creswell & Plano Clark, 2011), making it the most suited stance in addressing this project's pragmatic purpose, namely to inform the development of a physical activity intervention for individuals with HF. By adopting this approach, the focus of this research is placed on: (1) its future application, namely to inform the development of a physical activity intervention and (2) the importance of the question rather than the methods, meaning that the choice of methods employed in this project was dictated by the research question ('what are the factors that may influence physical activity?') and not a philosophical stance, such as positivism or constructivism.

The rationale for employing a mixed methods approach

As stated in section 5.1.4 the research questions determined the choice of the study design, namely an exploratory sequential mixed methods design. This section will provide a definition of the mixed methods approach to research, outline types of mixed methods designs and cases for when each type is appropriate and describe the rationale for the choice of the study design

Mixed methods is *'a third development movement following the development of qualitative and quantitative methods'* (Tashakkori & Teddlie, 2003), p5). It has been defined as a standalone research approach in which a researcher or a team of researchers combine elements of qualitative and quantitative research approaches on the following: epistemological stances, data collection methods, analysis, or inferences techniques (Johnson, Onwuegbuzie, & Turner, 2007).

Several theorists have developed typologies of mixed methods (Creswell & Plano Clark 2011; Greene & Caracelli 1997; Mertens 2005; Miles & Huberman 1994; Morgan 1998; Morse 2003; Tashakkori & Teddlie 2003). Creswell and Plano Clark (2011) have developed a six-type typology. These six mixed methods research design types are classified in accordance with (i) the overall design, (ii) timing of qualitative and quantitative elements of the study, (iii) weighting (whether more weight is placed on a qualitative or a quantitative phase), and (iv) how the findings of each phase are combined (mix).

The six designs are: convergent design, explanatory design, embedded design, transformative design, multiphase design, and exploratory design. A *Convergent design* is used when it is necessary to develop a complete understanding by collecting both quantitative and qualitative data, because each provides a partial view. Within this design, the qualitative and quantitative phases of the study are independent from one another in their design and conduct. An Explanatory design is used when it is necessary to use qualitative data to help explain aspects of or trends in quantitative findings (Creswell & Plano Clark, 2011). The Embedded Design is a mixed methods design in which one data set provides a supportive, secondary role in a study based primarily on the other data type (Creswell & Plano Clark, et al., 2011). The premises of this design are that a single data set is not sufficient, that different questions need to be answered, and that each type of question requires different types of data. Researchers use this design when they need to include qualitative or quantitative data to answer a research question within a largely quantitative or qualitative study. A *Multiphase design* is a design where several qualitative and quantitative phases are conducted over time and the project development is guided by previous phases (Creswell & Plano Clark, 2011). An *Exploratory design* is used to explore a topic, when the key variables are not known and to assess the extent to which qualitative results from a few participants generalise to a population, or to have an insight into the participants' perspective before the research question of a quantitative study can be formulated (Creswell & Plano Clark, 2011).

The exploratory design was chosen as the most appropriate for the present study because physical activity is a complex behaviour affected by a number of factors; the full set of barriers and enablers to physical activity in HF is not known; and an insight from people with HF is required to generate hypothesises. The overall design, timing of qualitative and quantitative elements of the study, weighting of the qualitative and quantitative findings and (iv) and the details on how the findings of each phase are combined (mixed) are summarised in Table 5.1.

Appendix N: Table 1. The study design.

Design type	Timing	Mix	Weighting
Exploratory	Sequential:	Connect the data between the two phases. The findings	QUAL; quan:

	Qualitative phase of the study will be followed by the quantitative phase.	of the qualitative phase will inform the design of the quantitative phase	Qualitative findings are given more weight than quantitative a priori because qualitative findings define the design of the subsequent quantitative study

Source: Adapted from Creswell & Plano Clark (2007: p 85)
This design is best suited to the aims of this project for several reasons. Firstly, the choice of design is dictated by the research questions of this study (outlined in section 5.1.4). Second, the complex set of factors and their interrelationships that may influence physical activity in HF are unknown. Thus, it is first necessary to explore the phenomenon. The sequential exploratory design is the most appropriate when the phenomenon in question has not been widely investigated because it enables the researcher to identify important variables that can then be studied quantitatively (Creswell & Plano Clark., 2011).

Appendix N. Figure 1. The steps for conducting the present sequential exploratory mixed methods study.

The steps for conducting the present exploratory sequential mixed methods study are described in Figure 5.1 and discussed below. In the present study, the exploratory approach will enable the researcher to identify a relevant theory or theories in the qualitative phase of the study and then to describe how this theory explains the variance in physical activity levels in HF in the quantitative phase. The use of the TDF-based interview schedule (described in detail in section 5.1.13.4) in the qualitative study will help to identify factors potentially relevant to physical activity in HF as perceived by participants. In the present study, the emphasis is placed on the qualitative component (QUAL) whilst the quantitative component (quant) plays the secondary role of expanding on the initial findings (Table 5.1). Therefore, the current mixed-method design, using the typology developed by Creswell & Plano Clark (2011) can be described as 'QUAL+quan' exploratory mixed methods design, where capitalisation is used to signify the emphasis being placed on the qualitative component (Creswell & Plano Clark et al., 2011). In exploratory sequential studies where a qualitative phase precedes a quantitative phase, inherently the qualitative phase is given more weight or prominence, because the findings of the qualitative data form the design of the quantitative data

(Creswell & Plano-Clark, 2007). Therefore, a priori the findings of the quantitative data are limited to the scope derived from qualitative data.

The decision to conduct an exploratory qualitative study first was made because barriers and enablers to being physically active are subjectively experienced by an individual with HF and therefore it is first required to explore all possible barriers and enablers as perceived by people with HF, before defining the variables of the quantitative study. This ensures that the perspective of people with HF was used in the design of the quantitative study, which, is expected to make the findings of the quantitative study more relevant. In other words, hypothesis to be tested are generated using participants' perspectives, as opposed to a researcher generating a limited number of hypotheses that are tested in a large-scale study. Phase 1 is designed to explore and identify the relevant perceived physical activity barriers and enablers in an interview-based qualitative study. Phase 2 will confirm and quantify the relationships between the identified barriers and enablers in a quantitative study using a larger sample.

To conclude, given the complexity of the phenomenon under investigation – factors influencing physical activity in HF - mixed methods approach is appropriate for the present study. The exploratory sequential mixed methods study (QUAL+ quant) was selected as the most appropriate for answering the research questions. This design, coupled with the effective use of the TDF, is appropriate for developing an evidence base for barriers and enablers of physical activity in HF. The steps recommended by Creswell & Plano Clark et al (2011), will be performed when implementing the present sequential exploratory mixed methods study.

When and how the findings of the study phases will be mixed

The two phases of the study are discrete in terms of data collection and analysis. The phases are mixed in the way that the findings of Phase 1 determine the design of Phase 2. The theoretical domains identified as the most relevant in Phase 1 will be used as the basis for the design of the quantitative follow-up.

Appendix O. Barriers to and enablers of physical activity in HF: the interview schedule.

Thank you for agreeing to be interviewed. We are interested in how people view physical activity and what may influence it. I would like to ask you some questions about this. I will start by asking you some general questions about physical activity and then go on to ask more detailed questions. If you would rather not answer a question that is no problem, we will move on. Do you have any questions before we begin? Are you happy to start? 1. PHYSICAL ACTIVITY - NATURE OF THE BEHAVIOUR • What do you do to be physically active? Prompts: Take me through your typical day/week? Do you plan the activities you are going to do? Examples? (*Behavioural Regulation*) What are you able to do physically? How confident are you in being physically active? (*Beliefs about Capabilities*) How does what you do compared to other people your age/with HF? (*Social Influence*) 2. CHANGE IN PHYSICAL ACTIVITY • What activities did you do before you got HF? Prompts: Has anything changed? In what way? Do you intend to do anything different in the future? Examples? (*Intentions*) Is physical activity a priority? (*Goals*) Are you optimistic/pessimistic about being physically active? (*Optimism*) 3. ENABLERS AND BARRIERS • What helps you to be physically active? • What stops you from being physically active? Prompts: Advice received; from whom? (*Knowledge*) Any advantages or disadvantages of being physically active? (*Beliefs about Consequences*) To what extent does physical activity play a role in your life? (*Social/Professional Role and Identity*) What do other people (your spouse/friends/family) think about what activities you should do? (*Social influences*) What about your home, surroundings, resources (costs; safety; time; weather; physical environment; cardiac rehabilitation)? (*Environmental Context and Resources*) Any particular skills or training needed to be physically active? (*Skills*) Do you receive any reward or praise for physical activity? What puts you off physical activity? (*Reinforcement*) How do you decide whether or not to be physically active? Do you ever forget to be physically active? What helps you focus or distracts you from being physically active? (*Memory, Attention and Decision Processes*) How does your mood influence what you do (e.g. fear; enjoyment)? (*Emotions*)

Note: prompts generated to cover each of the TDF domains. The domains are noted in brackets in *italics; the schedule was reduced from 48 prompts covering each constructs detailed by the TDF to the presented 18 prompts following expert and patient feedback, and piloting.*

Appendix P. Coding Scheme: additional clarification for the Theoretical Domains Framework definitions.

Coding Scheme Agreement

(1) Initially there were disagreements whether some responses belonged to Goal domain or to Intention domain. It was decided to code as Goal only when a participant mentioned where, or when they were going to engage in physical activity or referred to an amount of physical activity they were aiming to engage in (behavioural goal). In addition, any expression of a desirable outcome of physical activity was coded as Goal (outcome goal, i.e. 'I want to maintain independence'). Whereas Intention is a prior conscious decision to perform a behaviour to engage in physical activity (APA, 2015) and was coded when participant expressed the intention without specifying a particular goal.

(2) Inability to walk up the hill was initially coded as Beliefs about Capabilities, however, upon reflection, was coded into Environmental Context and Resources as participants referred to struggling with the landscape not necessarily reporting their ability. As such physical activity was restricted by the landscape and not defined by the participant's ability.

(3) Having a physical activity routine in place was coded as Behavioural Regulation when referred to as an action plan or a strategy to make sure that participant keeps physically active; Habitual or automatic performance of daily activity that was long-established was decided to be coded as Memory, Attention & Decision Processes (routine) and forgetting to perform the routine was also coded as Memory, Attention & Decision Processes.

(4) References to previous behaviour ('I have always done this, and therefore will do in future') was decided to be coded as stability of Intention. However, when a participant shares that they have always been active because it is congruent with who they are (or physical activity is a big part of their life) then it was coded as Social/Professional Role & Identity.

(5) Beliefs about Consequences and Reinforcement were also initially overlapping. It was decided to infer Reinforcement only when a strong evidence for a participant to keep engaging in physical activity due to the attainment of a desirable consequence was present in the text.

(6) ‘I enjoy physical activity’ was initially coded as Goal (intrinsic motivation). However, through consensus with the second and third coder was recoded into *Emotion domain.*

(7) Through consensus, the coders agreed that:

Heart attack, surgery (cardiovascular), hospitalisation, to be considered a health-related event and retirement to be considered a life event. Both meet the definition of a major life event - ‘important occasions throughout the lifespan that are either age-related and thus expected (e.g., marriage, retirement) or unrelated to age and unexpected (e.g., accidents, relocation)’ (American Psychological Association, 2007). The construct falls into the EC&R theoretical domain (Cane et al, 2012) and is defined as: ‘Salient events/critical incidents - occurrences that one judges to be distinctive, prominent or otherwise significant’. The author of the thesis beliefs that ‘life event’ is more representative of the quotes provided by the participants of the study and for the ease of reporting and consistency will use the terms ‘health event’ for ‘major health-related event’ and ‘life event’ for ‘ major life-related event’.

Appendix Q. Qualitative study: differences between participants

1.4.1.1 Differences between participants

The author of the thesis, being guided by the initial results of the TDF-based framework analysis, explored how each participant made sense of the local environment, facilities, implantable devices, and major events, and how these may have shaped their perception of physical activity. Some participants perceived these environmental resources as barriers and others as enablers, even when they were equivalent to each other for all participants. The subsequent analysis of the between-participant differences entailed grouping transcripts into three categories: those who self-identified as an active person, inactive person and did not specify. The author then explored patterns across these categories. The further investigation identified clustering of positive and negative beliefs across the domains, accordingly to whether the participant self-identified as active (n=7), inactive person (n=3) or did not specify (n=4).

People who self-identified as physically active talked more about enablers to physical activity than those who did not self-identify as physically active, as indicated by the number of quotes, $F(df = 2; 15) = 16.27$, $p<0.001$. The number of quotes suggesting that the domain was an enabler was significantly larger for individuals who self-identified as active, compared to both, non-active, 95% CI:[34.33: 10.67], and those who did not specify. The number of quotes did not differ between those who did not specify and those who self-identified as inactive. There were no statistically significant differences across these groups in the number of quotes describing barriers, $F(df = 2; 15) = 1.48$, $p = 0.26$. The differences in the number of positive and negative beliefs about physical activity barriers across the relevant Theoretical Domains Framework are reported in Appendix Q.

1.4.1.1.1 Confidence to engage in physical activity across self-identity categories

The quotes describing diminished confidence due to heart condition were summarised as the following belief statement:

I lack confidence in engaging in physical activity because of my heart condition

Four participants who self-identified as ‘active person’ talked about their confidence to engage in physical activity given their heart condition. They tend to overcome the lack of confidence and still engaged in physical activity. Participant 1 for example, although experiences diminished confidence since ventricular tachycardia (VT) event, still nevertheless pushed himself to exercise:

> *Participant 1: Once I got over that loss of confidence... yeah physically, again... so difficult to know what is psychological or physical....but what happens in VT is that the heart increases at very high rate, to something like 180 - 200 beats a minute... and that triggers VT... and whether it is that elevated heart beat per minute rate that makes you feel ill for a few days, or whether: Oh my God, why did that happen?' that puts into: oh maybe I shouldn't do anything' mode ' I don't feel very well'. It could be both... but after a while you begin physically feel more relaxed and that in itself prompts you to say: 'OK, I will get up and do some exercise*

Similarly, Participant 8, who also self-identified as an active person, and engaged in a large amount of walking (Fitbit steps recording at the interview >30000 steps a week), expressed that he is highly confident in engaging in physical activity:

> *Interviewer: How confident are you in walking from 1 to 10? Participant8: Yes, I am 10.*

However, he did express that he is not confident in performing other modes of physical activity (e.g. gym, running):

> *Participant 8: Do you intend to do anything differently in future in terms of your activities? Participant8: No, this is my ability. I cannot do more than this. I cannot go to the gym and I can't run... even I started to run a bit... I can't run because of my heart. So, this is what I do, and I think it suits me and I'm happy to do that [walking]. I can't do more than that.*

Participant 16 described his reduced confidence in engaging in physical activity, that was caused by safety concerns given his heart condition. Yet this lack of confidence and concerns did not stop him from engaging in physical activity that is safe given his heart condition:

> *Participant16: My heart has been damaged, and it therefore, what is generally called HF, but, but HF is a very misleading term because it suggests...pfff... There are degrees of HF. So, I think of it as a damaged muscle in my heart which prevents me from working at full strength. Interviewer: And thinking that... does that*

change how much you do? Participant16: No, it does not, I mean I first find out what is safe to do I get, I ask for medical opinion first, because it would be silly to go ahead and do things that might cause damage.

Thus, those who self-identified as physically active, although experienced lack of self-efficacy to exercise due to the condition of their heart, nevertheless, performed modes of physical activity that they felt comfortable with – walking. They have limited their ability to engage in modes of physical activity that involve ‘working at full strength’, and generally did not engage in activities that are too strenuous given their heart condition. One participant, who was extremely sedentary but did not share belief statements that can be categorised as Social Professional Role and Identity, expressed lack of self-efficacy caused by his heart condition:

And before this medication, how much did you use to do? Participant9: Before then my heart was very poor [highlights ‘very’ with intonation]. I had to stop every 2 steps. At the hospital they said: ‘we can’t do anything about it...but one side of your heart is not working properly’. Then I lost this weight, my heart is better, but I am very weak...and my blood pressure is very low. Doctor said that I have to change tablets for my blood pressure, so now I take 33 tablets a day.

Participant 9 seemed to limit his walking due to the salience of the poor condition of his heart and the prescribed medication. Thus, whilst self-identified as active Participant 16, thought of ‘degrees of HF’ and a ‘damaged muscle’, when describing his condition, Participant 9, who was extremely sedentary, perceived his heart as ‘not working properly’ and ‘very poor’. Thus, it seems that the perceived degree of heart’s damage corresponds to the level of physical activity the participants are confident to perform.

It seems from the transcripts that self-efficacy beliefs were well-formulated and detailed among individuals who self-identified as ‘active person’ but not others. Those who self-identified as ‘active person’, had a good understanding of their physical ability given HF. They perceived a gradient in their ability as opposed to radical and uncompromised belief in absolute lack of ability. The lack of confidence to engage in physical activity caused by experienced heart condition was a significant barrier to engaging in physical activity, initially. However, it was successfully overcome with time. In addition, those who self-identified as active discriminated between self-efficacy required to engage in moderate activity and self-efficacy required to engage in vicarious exercise. Whereas, it is likely that individuals who did not identify as active, generalised their lack of physical ability to all modes of physical activity.

1.4.1.1.2 HF Comorbidity related self-efficacy and self-identity categories:

Six out of the 12 participants who self-identified as 'active person' described that comorbidities diminish their ability to engage in physical activity. However, they perceived it as something that 'slows them down', requires to 'pace themselves', rather than something that is insurmountable and requires to eradicate physical activity of any mode, amount or intensity.

> *Participant 1: Is it walking part you find difficult or…? Participant1: well…because I got Arthritis. Interviewer: OK Participant1: that is you know…that slows me down…and makes me...that if anything… is the disincentive to a lot of exercise…it is nothing to do with the heart…it is to do with…my Arthritis..And as I said. The determinant is actually I am governed more by this Arthritis…than anything to do with my heart at all…*

> *Participant 7 (71, female): Well, not really…erm...you know...I couldn't go so fast but that is because my hip isn't so good, and I know gradually as the surgeon said at the time I need a new left knee. Those are the things that really hold me up. All right. I don't get any breathless at night. I can't do at times during the day. If I if I hurry too much. So, I've learned how to pace myself.*

All participants who self-identified as inactive person reported comorbidity-related limitations to self-efficacy. Whereas, participants who identified as inactive person often spoke about physical activity categorically as something they would not engage in:

> *Participant 4: cause of asthma, actually. When I used to be too active, that would set it off. So I have to be careful, you know. […] I perhaps get a little bit depressed… If I can't do things because of the asthma. I think that has been a problem...a lot of my life. It has prevented me...perhaps living a full life that I could have done. I just instinctively curtail my activities to suit that.*

Participant 6 wouldn't do any exercise:

> *Let's put it that way. Interviewer: Why is that? Partcipant6: Because I get breathless very quick and...We said about my blood pressure...there are lots of things, few things that I can't do now, some are related to age, and some are related to blood pressure.*

Three out of five participants who did not describe themselves as either active or inactive felt that comorbid conditions were the main barrier to their engagement in physical activity and also felt that they could not engage in any form of physical activity:

> *Interviewer: And what discourages you? Participant3: I don't know.... Sometimes it is my legs... They hurt.. Especially around here (shows around knees).*

This limitation was generalised to low-impact activity like walking as well:

> *Participant9: Another doctor for my lungs…they are very bad, I take six capsules for my lungs. Interviewer: Does that get in the way of you exercising or walking? Participant9: No, no, no I can't. I am 80 years old, I have a lot of medical problems…*
>
> *Interviewer: How confident are you and doing things like gardening or walking?*
>
> *Participant10: Well, walking…I have arthritis, arthritic knees…walking is a wee bit of struggle and makes me puff…*

1.4.1.1.3 Age-related self-efficacy and self-identity categories:

Participants who did not self-identify as 'active person' may have categorised as an older adult, and did not perceive physical activity as congruent with physical activity, Participant 3 for example shared that his older age is incompatible with long walks:

> *I don't think at my age you can think about that. […] because a guy of 26 or 27 can do an hour. They are fit…but they can't expect me I am 80… they can't expect me to do that... I know and they know my possibilities*

Participants who self-identified as inactive person did not see themselves as athletic due to their age:

> *Participant 13: I assume it is part of getting older, obviously bodies wear out, don't they? I can't see me being the top-class athlete anymore…it is a question of I can manage to do, rather than what I would like to do.*

Individuals who had a strong self-concept of an active person shared that they still engage in physical activity despite getting older:

> *Participant 15: If you do my breathing and a mixture of stretching and as I said yoga and Tai chi. It depends how much my body can take. I don't like to stretch my body too much, okay? Obviously, I am getting old.*

He was determined to engage in physical activity despite their age and showed great persistence and resilience to physiological changes associated with age:

> *I am still very active. Yesterday, I was actually climbing trees, and I am 77 years old. And doing hedges and you know gardening. Erm. I walked for miles on the flat…Erm any incline starts giving me problems. Some days are much better than others. I feel I have*

> *to push myself. Erm...I resist sitting down and do nothing. And when I made the decision to do something, I make sure I do that.*

Thus, self-identity influenced how the participants responded to age-related limitations to their ability. Those, who had a strong self-concept of oneself as an active person, resisted sedentary lifestyle. On the contrary to them, participants who did not self-identify as an active person, perceived physical activity as incongruent with self-concept of an older adult and were less determined in maintaining physical activity in the face of a barrier like older age. In conclusion, 'older adult' and 'active person' maybe a competing self-concept, that influence whether physically active lifestyle is congruent with self or not and subsequently affected how much the participants engaged in physical activity.

1.4.1.1.4 Self-efficacy, symptoms of HF and self-identity

None of the participants who self-identified as an active person, and for whom physical activity was a big part of their lives reported symptoms when asked about the barriers to their physical activity.

1.4.1.1.5 Differences in Environmental Context and Resources

1.4.1.1.5.1 Implantable Device

None of those who did not self-identify as physically active have the implantable device fitted.

1.4.1.1.5.2 Major event across self-identity categories

Major health event was reported as both a barrier and an enabler, Participants who had a strong self-concept of an active person, did not report major health event as a negative influence on their levels of physical activity. As such, the belief statement: 'my physical activity has decreased since a major health event' has not been shared by participants who self-identified as an active person.

Even when talking about a very recent major health event (less than one month), and a subsequent temporary (less than one month) period of prescribed inactivity, the participants tend to describe how they are planning to bounce back to normal activity levels, when it is wise to do so. Participant 16, for example, shared that he only interrupted his physical activity because he had an operation:

> *'It is only in the last 10 days...[since being out of hospital]. I used to exercise before but when I had my valve operation here, I was told to avoid this kind of exercise because it, it didn't help while I was going through that... so, it's been some time since I had a regular exercise regime... Once you do it becomes second nature you do it because you want to, and its reward is that you feel better.'*

Participant 16, as is seen above, talked about physical activity as his second nature, whereas mentioned the major health event (valve operation) as a temporary disruption, not a long-lasting barrier. It is also apparent from the passage above that physical activity is formed habit and physical activity is reinforced. Thus, despite being asked about the major event the participant mostly talked about how his habitual physical activity ('second nature') and intrinsic motivation ('you want to, and it is a reward') withstand the barriers temporary imposed by major health event.

In contrast, Participant 13, who have self-identified as 'I have never been an athletic person', was not as positive and keen on physical activity. When asked what the reasons are for her not using the stationary bike at home she responded:

> *I mean, it is only a matter of weeks since I had this major surgery. I had it 22nd of June [four weeks] and it was a huge operation...I had 45 clips...so, obviously I wasn't running around the block, was I? I was advised to pick up heavy weights...I am walking slower than I would like to walk. But on the other hand, I get where I want to. [Interviewer: I am sorry to hear this ...But before the 22 of June did you use to exercise or use a bike...] No not really...I had an operation three years before that. But when this treatment is done and over with, I should be down to being monitored. So, then I can really think about it...*

Participant 1 and 8 self-identified as physically active people. However, they have also specified that this was a consequence of a major health event. It seems from the quotes, that a major health event – a heart attack – shaped their new behaviour and also resulted in reconceptualising oneself as an active person. The major health event has created an identity shift in Participant 1 and 8. Participant 1 referred to heart attack as a 'trigger' and a 'catalyst' for change.

> *Participant 1: Yeah that's what I do. I mean this started... I wasn't physically active before I had my heart attack. This is new. It only came about, really, as a consequence of a heart attack in 2001... and in those days, they probably still do, you had you know rehab... and it involves doing exercise... in a gym...erm For half an hour or so, you know... structured exercise...So, the heart attack was a trigger, the catalyst for change.*

Participant 8: When I had the surgery, I became fit

Those who self-identified as ‘active people’ were resistant to onset of a sedentary lifestyle following a major health event (n=7). Major events acted as a ‘catalyst’ for a positive lifestyle change for some who were never an ‘active person’ before (n=2).

1.4.1.1.6 Goal and goal priority across self-identity categories

Individuals who self-identified as active person had a strong behavioural goal to be physically active and this goal was of high priority to them. To illustrate:

> *Participant 2: I feel I have to push myself. Erm…I resist sitting down and do nothing. […] Well, you know, I've got to do it.*

They shared the following *Goal* beliefs more frequently than those who did not:

I already engage in as much physical activity as I am able to (number of quotes, k=7 compared to zero quotes in those who did not self-identify as active people)
I have integrated an adequate amount of physical activity into my life (number of quotes, k=9 compared to one quote in those who did not self-identify as active people)
Engaging in physical activity is a priority for me (number of quotes, k= 16 compared to four quotes in those who did not self-identify as active people)

1.4.1.1.6.1 Intrinsic and extrinsic motivation across self-identity categories

Participants who self-identified as active person, also strongly believed that physical activity will improve their health and result in attaining functional independence. As such, those who identified as active people shared (20 times: n = 7; k =20) the following belief statement:

‘I engage in physical activity to be able to get on with life without help from others’

Whereas those who identified as ‘inactive person’ did not hold this belief at all (n = 0; k=0). Thus, people who did not identify as physically active, did not have a strong extrinsic motivation to engage in physical activity. The quotes supporting this belief are provided in section above: Goal Domain.

1.4.1.1.6.2 I enjoy engaging in physical activity

The intrinsic motivation (behavioural goal and enjoyment of physical activity) to engage in physical activity was a strong positive influence on physical activity. People who identified as ‘active person’ tend to have an intrinsic motivation to engage in physical activity:

Participant 8 for example would engage in physical activity even during hospitalisation:

> *[...] well, the same feeling outside the hospital or inside the hospital. I don't want to miss the happiness of my walking and being active... [Interviewer: Does it give you enjoyment?] Participant8: I enjoy it a lot. Yes, that's a good word you used.*

People, who did not identify as an active person (n=3) lacked an intrinsic motivation to exercise and did not value the behaviour. Participant 3 who did not self-identify as active person when asked if physical activity is something he enjoys, reported: 'No, it is not an enjoyment, it is an obligation.'

People who identified as 'inactive person' expressed a belief that physical activity is beneficial for them (Beliefs about Consequences) yet this did was not internalised as a motivation to engage in physical activity:

> *'Participant 6: it is a sensible thing to do...to walk...because you get the blood moving and going up to the brain[...]I know that I am never going to be one of these people who are jogging and running the marathon and things like that...I have never ever....and I won't do in the future either, because I am too lazy.'*

Similarly, Participant 13 when asked if she is aware of any benefits to physical activity shared:

> *' It keeps your blood circulating...yes fair enough... as the years go by, it seems that they are things I don't want to do...'*

The only one inactive participant who did described an intrinsic motivation to engage in physical activity still talked about it in a retrospective matter:

> *'Participant4: I enjoy walking. We enjoyed walking. We always walked. I walked since I was in my teens, really...just left school. We would go out with friends and walk... [Interviewer: And now?] Participant4: I would really enjoy that. [...] What I used to enjoy when I used to walk with friends, it is very relaxing, if you had any mental...if you got a bit stressed over anything you could sort of walk it out and chat...we used to go and visit...erm...Stately Homes...as it was on the way...and we enjoyed ourselves, really. [Interviewer: And these days?] Participant4: I don't do that.'*

In summary, self-identification as 'active person' was observed in participants who also shared an extrinsic motivation to remain functionally independent as well as those who were intrinsically motivated to engage in physical activity. Whereas, individuals who did not self-identify as active person did not have an extrinsic motivation (outcome goal) to engage in physical activity at all. They also did not seem to internalise the belief about consequences as a personal goal.

Behavioural Regulation across the categories of self-identity

People with a strong self-identity of an active person, talked about Behavioural Regulation – monitoring, action planning, and implementation intentions –considerably more (n = 7; number of quotes, k = 36) than those who self-identified as non-active (n = 3; number of quotes, k = 2). This is further described in section: (Behavioural Regulation.

Participants who self-identified as physically active, all listed strategies that optimize their physical activity performance given the declined physical capability Capability-corresponding planning and monitoring activity with a goal. This involved pacing activities. Participants who did self-identify as physically active, adopted the following strategies that promote physical activity:

monitoring physical activity to ensure that the behavioural goal is met;

and implementation intentions to ensure that behavioural goal is met despite barriers, like weather, forgetfulness.

Appendix P. Positive and negative beliefs about physical activity barriers across the relevant Theoretical Domains Framework

Theoretical Domains Framework	Barrier, number of quotes (k)	Enabler, number of quotes (k)
Environmental Context and Resources	Self-identified as active (n = 7): k = 14	Self-identified as active (n = 7): k = 33
	Self-identified as inactive (n = 3): k = 17	Self-identified as inactive (n = 3): k = 5
	Did not specify self-identity (n = 4): k = 21	Did not specify self-identity (n = 4): k = 1
Beliefs about Consequences	Self-identified as active (n = 7): k= 16	Self-identified as active (n = 7): k = 36
	Self-identified as inactive (n = 3): k = 8	Self-identified as inactive (n = 3): k = 2
	Did not specify self-identity (n = 4): k = 21	Self-identified as active (n = 7): k = 0
Goal	Self-identified as active (n = 7): k = 12	Self-identified as active (n = 7): k = 35
	Self-identified as inactive (n = 3): k = 5	Self-identified as inactive (n = 3): k = 0
	Did not specify self-identity (n = 4): k = 17	Did not specify self-identity (n = 4): k = 0
Beliefs about Capabilities	Self-identified as active (n = 7): k = 26	Self-identified as active (n = 7): k = 6
	Self-identified as inactive (n = 3): k = 14	Self-identified as inactive (n = 3): k = 0
	Did not specify self-identity (n = 4): k = 12	Did not specify self-identity (n = 4): k = 0
Social Influences	Self-identified as active (n = 7): k = 4	Self-identified as active (n = 7): k = 24
	Self-identified as inactive (n = 3): k= 0	Self-identified as inactive (n = 3): k = 14
	Did not specify self-identity (n = 4): k = 9	Did not specify self-identity (n = 4): k = 9
Behavioural Regulation	Self-identified as active (n = 7): k = 12	Self-identified as active (n = 7): k = 23
	Self-identified as inactive (n = 3): k =1	Self-identified as inactive (n = 3): k = 1
	Did not specify self-identity (n = 4): k = 12	Did not specify self-identity (n = 4): k = 12

Note: quotes that support positive valence of the enabler belief statement (e.g., 'I enjoy physical activity') and negative valence of the barrier belief statements (e.g., 'no, I do not forget to perform physical activity routine'

Appendix P. The number of quotes that were coded as positive or negative contamination for individuals who self-identified as optimistic or did not.

Participant	Positive contamination		Negative contamination		Explanatory style tendency
	Present	Not present[17]	Present	Not present	
Did not self-identify as optimistic					
Participant 1	5	60	0	65	Positive
Participant 3	0	70	6	64	Negative
Participant 4	0	72	0	72	Neutral
Participant 5	0	19	0	19	Neutral
Participant 6	0	72	1	71	Negative
Participant 9	0	32	6	26	Negative
Participant 10	0	47	0	47	Neutral
Participant 12	0	15	2	13	Negative
Participant 13	3	61	3	62	Neutral
Participant 15	5	47	0	52	Positive
Self-identified as optimistic					
Participant 2	1	32	0	33	Positive
Participant 7	5	69	0	74	Positive
Participant 8	6	42	0	48	Positive
Participant 11	0	55	0	55	Neutral
Participant 14	1	44	4	41	Negative
Participant 16	2	58	0	60	Positive

[17] Neutral quotes are coded as ‘not present’ positive and negative contamination.

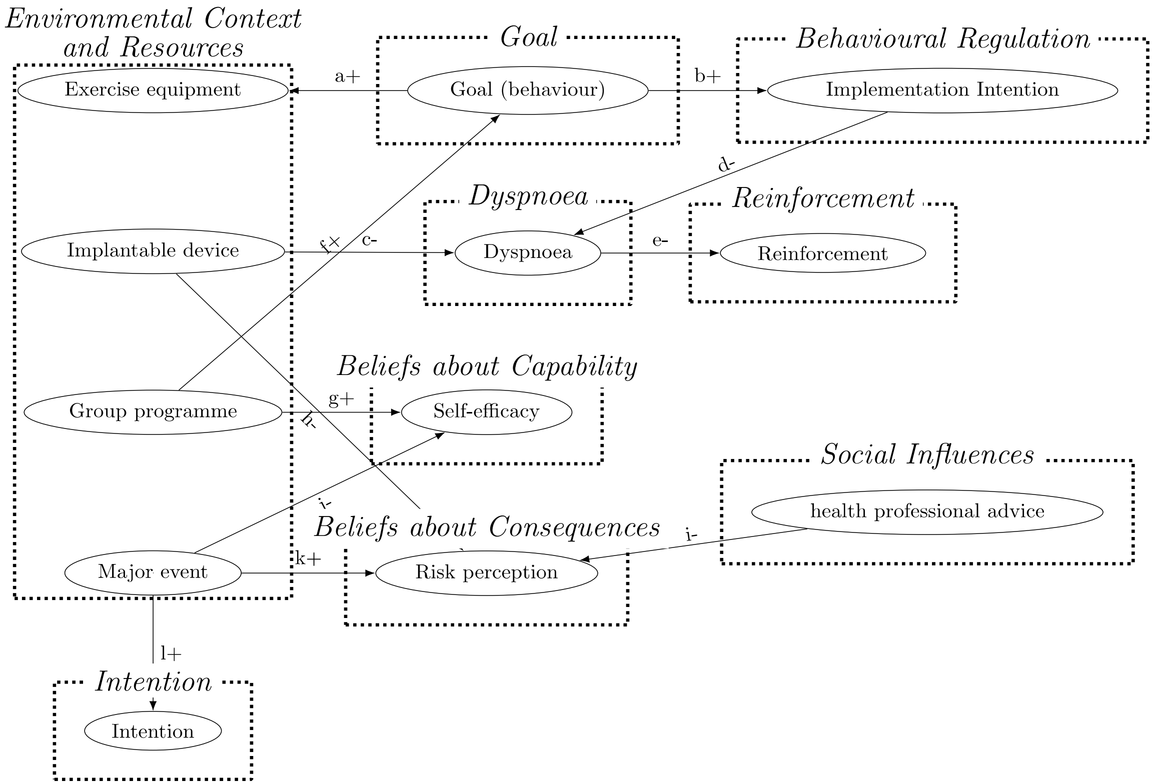
Appendix R. Lexico-syntactic patterns analysis results

Participant 1: *Causal links among the TDF domains (and corresponding beliefs) evident from lexico-syntactic pattern*

Linked domains	Lexico-syntactic pattern	The analysis of the instantiating quote and the lexico-syntactic pattern (in green)
(a+) Goal Environmental Context and Resources	Linking word ‘why’	The outcome Goal to remain independent (Goal) pushed Participant 1 to buy an e-bike (ECR) *I was dependent on my wife carrying me up… and daughter…carrying me up to the gym to do the aqua aerobics… (and of course part of the boredom factor, if you like…that’s engendered.) That’s why I bought the e-bike*
(b+) Goal Behavioural Regulations	Linking word ‘why’ A counterfactual statement	He formulated action plans (*Behavioural Regulations*) to ensure he attains his *Goal*. The lexico-syntactic patterns such as ‘why’ link and counterfactual statements (in green) are evidencing this causal links: *well, I was trying not to be, I was dependent on my wife carrying me up… and daughter…carrying me up to the gym to do the aqua aerobics… (and of course part of the boredom factor, if you like…that’s engendered.) That’s why I bought the e-bike… I was… at least I could I get around independently, without having to depend on my wife or daughter*
(c+) Environmental Context Resources Dyspnoea	Linking word ‘part of that’	The implantable device (ECR) helped to attenuate dyspnoea (Dyspnoea) *I don’t get out of breath. Other than the same way anyone would…you would. Interviewer: Ok I see. Participant: Part of that is that I have an ICD implanted which has a pacemaker, which increases the heartbeat as it detects it is needed*
(d-) Behavioural Regulation Dyspnoea	If-then	Participant 1 employed an implementation intention (*Behavioural Regulation*), such as pacing when feeling unwell, in order to control breathing and avoid experiencing Dyspnoea. *if you start immediately running: 'Oh Gosh' (imitates breathlessness, places hand on the chest) you get out of breath but after a minute or so and you think you just pull back a bit …I'm just going to take easier for a minute.*

(e-) Dyspnoea (lack of) →Reinforcement	Linking word ‘because’	The attenuation of dyspnoea was described to cause reinforcement of physical activity:
	A counterfactual statement	*the …it is because you actually physically feel good, oh that’s quite good. I don’t feel as nearly as breathless or in pain as I thought I would be… and as you said that just build on and I just carry that on…*
(f+) Environmental Context Resources →Goal	Causal verb	*‘...and in those days, they probably still do, you had you know rehab… and it involves doing exercise… in a gym…erm For half an hour or so, you know… structured exercise… and it was there I first learnt: ‘do as much as you feel comfortable with.’*
(g+) Environmental Context Resources → Beliefs about Capabilities	Causal verb	*Interviewer: and what did influence the change? Participant1: Actually, one thing that did [influence] was going to cardiac rehab. To be honest, that was..it was like ..’Oh God I am too weak to do this’, and they would say: ‘no, you are not, you can walk up that 5 yards there, can’t you?’ … ‘ok, I can do that’*
(h+) Social Influences →Beliefs about Consequences	if-then statement	An advice from a clinician (*Social influences*) caused the lack of the physical activity risk perception (*Beliefs about Consequences*): *Yes! You look up to professional and you need that reassurance to say: ‘what I am doing now, is not going to impact on my long term health’; ‘is it the right thing to do?’ and if the answer comes back from a professional you trust, and I have implicit trust, explicit trust as well, in my consultant...then if she says: ‘that’s a good thing to do’, then I will do it*
(i-) Environmental Context and Resources →Beliefs about Capabilities	When-then statement Counterfactual statement	A causal link between health-related event (ECR) and the loss of confidence (Beliefs about Capabilities) was described in a when-then statement and in a counterfactual statement: *When you have one of these events, and the last one in February and it was like: 'Ah, not again!' kind of feeling, and kind off… I don't know if it was real or it is psychological...[…] I saw my consultant 10 days, or whatever later, she said the same: that’s what it is, therefore, just get one with your life and move on'. So, that gives you a lot of confidence. But that loss of confidence after the event: 'oh I can’t do any exercises' sort of thing…but that is short lived, because after a few days… life goes on, doesn't it? So in that event I got back to normal exercise, about…let’s say… after three weeks*
(j-) Environmental Context and Resources → Beliefs about Consequences	A counterfactual statement	The events – the heart attack (*Environmental Context and Resources*) was followed with perceived risk and fear:
	Linearity (‘what happens after’)	*… so many of the barriers, if there are any, are they are more about fear of consequences, it is a psychological thing… rather than anything which says: there is no reason…erm… you could look at it and say there is no reason why I shouldn't do exercise...and you know that...and you think:' just get on and do it'…or there is that fear bit that comes in and you think: 'maybe I shouldn't' … it is that conflict between: 'there isn't really a problem' and 'but hold on a second I just had a problem'… and it takes a while to get over that psychological. Through*

		that...erm…it is the fear, it is what happens right after...OK, you have a heart attack and you have damaged your heart.
Environmental Context and Resources → Intention	Linearity (' as a consequence ') Causal verb (came about)	*I wasn't physically active before I had my heart attack. This is new. It only came about, really, as a consequence of a heart attack in 2001*

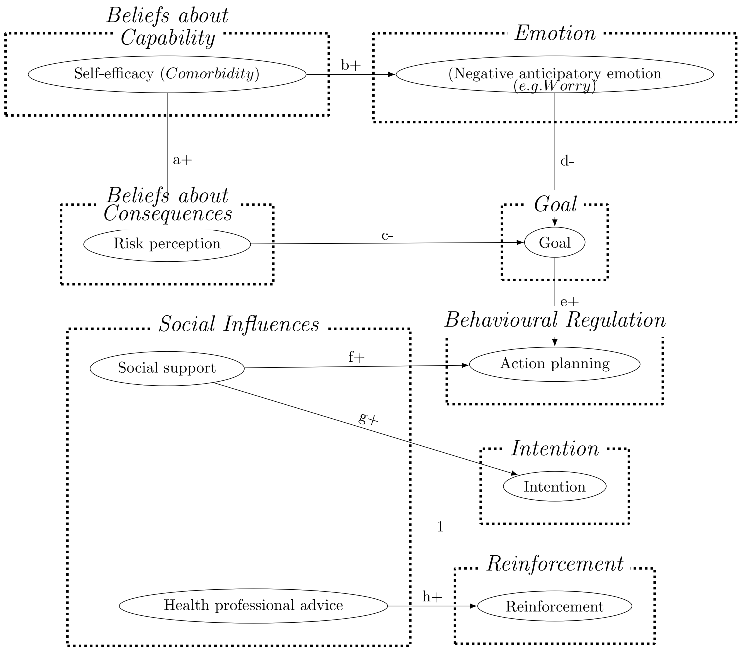


Participant 1: The causal graph depicting perceived causal links induced by the lexico-syntactic patterns in this participant's transcript.

Participant 2: Causal links among the TDF domains (and corresponding beliefs) evident from lexico-syntactic pattern

Linked domains	**Lexico-syntactic pattern**	**The analysis of the instantiating quote and the lexico-syntactic patterns (in green)**
(a+) Beliefs about Capabilities (reduced due to comorbidity) Beliefs about Consequences (negative)	When-then statement A counterfactual statement	*I have my Heart…heart problem, I have atrial fibrillation […] And Erm…when I go to the gym, a lot of machines have this heart monitor thing. And sometimes when something goes off the sky…ooouh [tone of uncertainty], Shall I be doing that?' So, I just slow down a little bit and start again. I try to keep my heart rate under 130.*
(b+) Beliefs about Capabilities (lack) Emotion (negative)	The linking word 'because'	Worry (Emotion) was causally linked to atrial fibrillation (Beliefs about Capabilities): *I am worried about the gym, because not only do I have my Heart…heart problem, I have atrial fibrillation as well, all the time.*
(c-) Beliefs about Consequences (negative) and Goal	When-then statement	And sometimes when something goes off the sky…ooouh [tone of uncertainty]. I [then] just slow down a little bit and start again…I try to keep my heart rate under 130.
(d-) Emotion and Goal		*Shall I be doing that?' So, I just slow down a little bit and start again. I try to keep my heart rate under 130. But you know sometimes these things don't work as they should, and I am getting worried at the moment.*
(e+) Goal Behavioural Regulation	A counterfactual statement	The causal link between the outcome goal to remain independent (Goal) and action planning (Behavioural Regulation) was articulated as *No, because I know I got to do it to stay where I am. I know it is going to give me a problem … I could use the station's lift…but It is important that I don't… but, you know, with what I got, and the atrial fibrillation as well, I mean, it could have been acceptable for me to sit in a chair in a nursing home, basically… OK? But I dread the thought of that… so, I keep going.*

			Participant 2 shared that making plans with others (Social Influences) improves his (Behavioural Regulation). These domains were linked through the use of a counterfactual statement. This suggest that Participant 2 relies on social support in making plans:
(f+) Social Influences Behavioural Regulation		A counterfactual statement	*Yes, I do…I think…when I have decided to go out or scheduled to go somewhere…it normally takes me, as I said up to 10:30 to get ready but if somebody says I am going to pick you up at nine. I actually can be ready by nine.*
			He sourced his Motivation in social relationships and engagements. He was more motivated to exercise when with others. He would not form an Intention to engage in physical activity without social support (*Social Influences*) as it is evident from the counterfactual statement below:
(g+) Social Influences Intention		A counterfactual statement	*Yeah it is really, I copy after them (smiles)…Erm…I try to control my weight a bit…but…I have lost some recently. I should I should…again it is in the head, I got machines at home I could exercise on….but when I am by myself, I don't really have the motivation to do it.*
			Participant 2 modelled his behaviour on the behaviour of his friends ('*I copy after them'*) indicating social learning as one of the mechanisms via which physical activity behaviour is socially transmitted.
(h+) Social Influences Reinforcement		A counterfactual statement	*He [HF consultant] thinks I am quite remarkable. He never said that I should stop, he is pleased with these things I do*

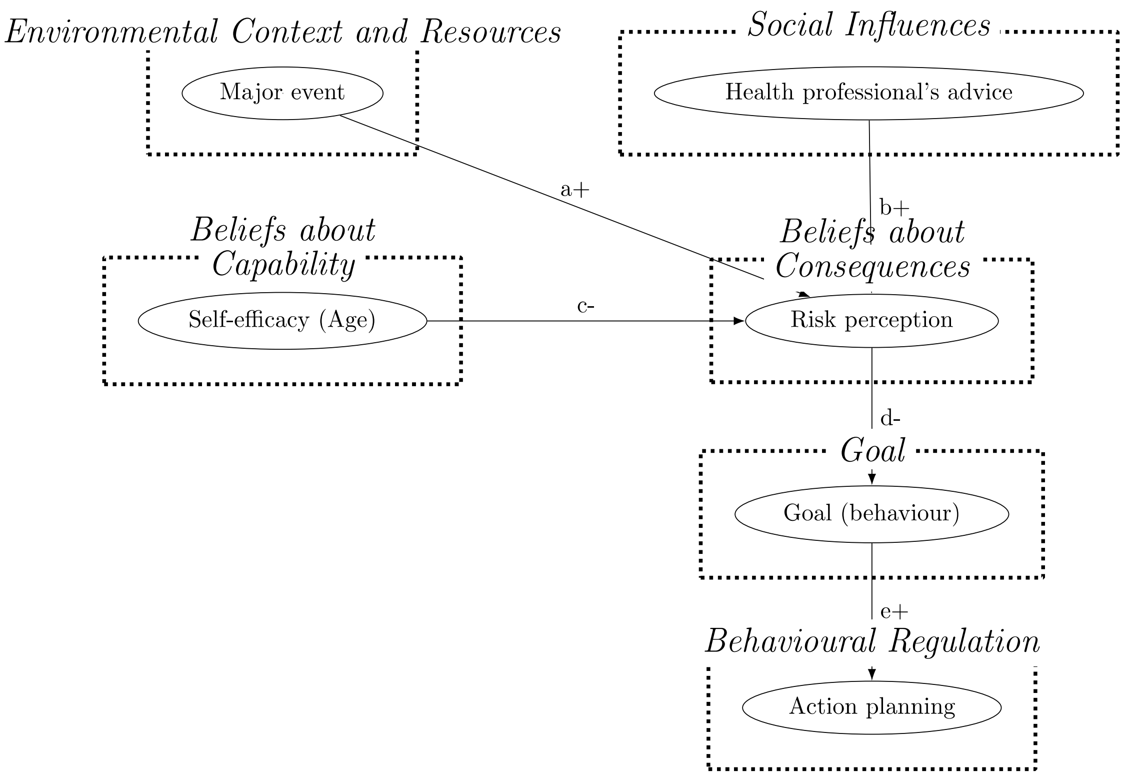


Participant 2: The causal graph depicting perceived causal links induced by the lexico-syntactic patterns in this participant's transcript.

Participant 3: *Causal links among the TDF domains (and corresponding beliefs) evident from lexico-syntactic patterns*

Linked domains	Lexico-syntactic pattern	The analysis of the instantiating quote and the lexico-syntactic pattern (in green)
(a+) *EC&R* Beliefs about Consequences	A counterfactual statement	Major health-related event – bypass surgery – caused risk perception and negative outcome expectancy. The participant under uncertainty, interprets somatic sensations and symptoms in his chest as signs forecasting a negative outcome (i.e. decompensated HF). He often pauses walking when experiencing this sensation: *it [walking] makes you burp… but when I get chest pain…that's when I stop… because it could be something else…so I stop…and go home and relax…and then pain goes away, and I know it is not the heart…it is the stomach …when you get pain especially on the left side… it could be lung, it could be stomach… but if you had bypass…the take a vein from a leg, they put it in your heart…it has to be…to pump the blood* The participant reasoned the causal link through the use of the counterfactual argument (in green).
(b+) Social Influences Beliefs about Consequences	A causal linking word	*Because, you know… today I have done a bit of walking, and that's enough, you cannot overdo it. You tell your doctor that… they tell you off… they get upset if I don't do 22 minutes per day, and they get upset if you say I walked 45 minutes, Because they think some things might happen.*
Beliefs about Capabilities Beliefs about Consequences	A counterfactual statement	*(c-)* *I don't think at my age you can think about that. 22 minutes is aright… it is all very nice to give instructions to your patients… but this is not the doctor's idea… because the guy of 26 or 27 can do an*

		hour. They are fit…but they can't expect me I am 80… they can't expect me to do that.
Beliefs about Consequences → Goal	A causal linking word	*(d-)* *Because, you know… today I have done a bit of walking, and that's enough, you cannot overdo it. You tell your doctor that… they tell you off… they get upset if I don't do 22 minutes per day, and they get upset if you say I walked 45 minutes, Because they think some things might happen*
Goal → Behavioural Regulation	If-then statement	*(e+)* *I bought this wristwatch, it is like a watch, but it tells you how many steps you have done. Interviewer: Ah right! Does that help you to do more? Participant3: Well, no, it helps me to stop, cause if I have overdone 22 minutes. But I don't look at it until I feel I have done enough. 'Let's have a look at this.. oh well, it is over half an hour'...and then I stop. It is never more than 22*



Participant 3: The causal graph depicting perceived causal links induced by the lexico-syntactic patterns in this participant's transcript.

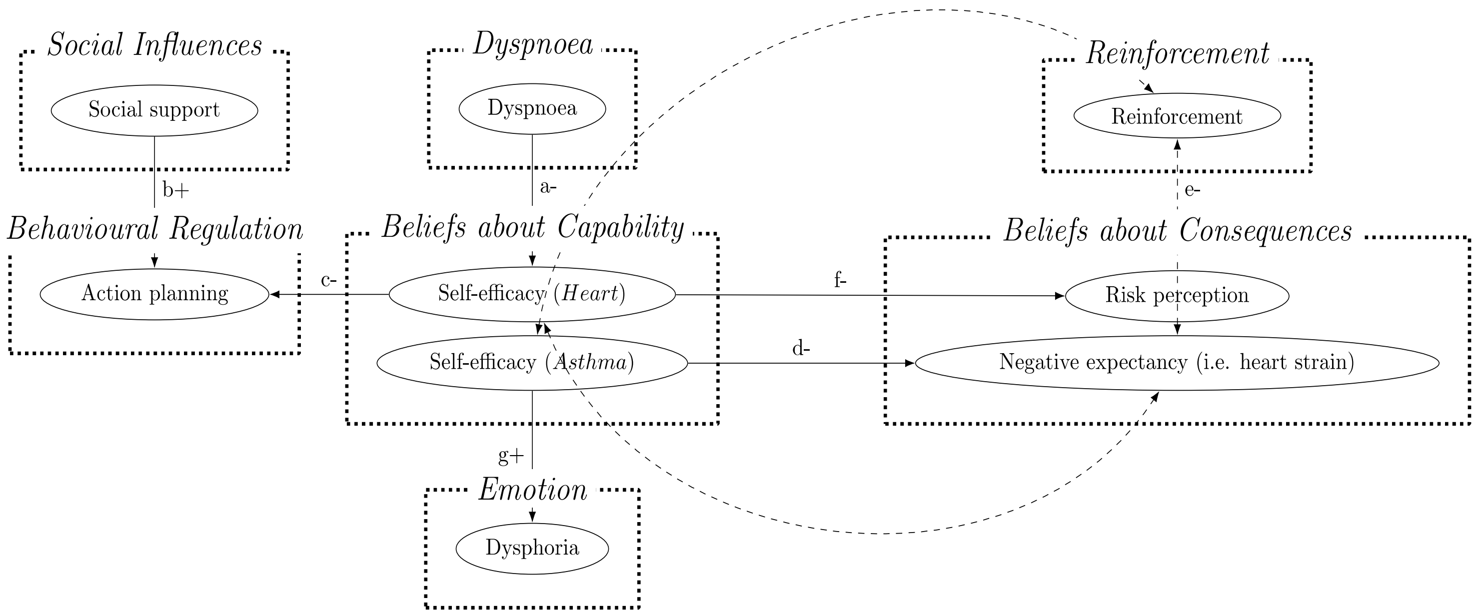
Participant 4: Causal links among the TDF domains (and corresponding belief) evident from lexico- patterns

Linked domains	**Lexico-syntactic pattern**	**The analysis of the instantiating quote and the lexico-syntactic pattern (in green)**
(a-) Dyspnoea → Beliefs about Capabilities	If-then statement	*When I go out and walk in fresh air without having nasty fumes all around then obviously I can walk further and better. If I have a holiday, in a country, with good air, then I can walk better from the beginning and walk further without having to use my inhaler very much. And I generally feel fitter.*
(b+) Social influences → Behavioural Regulations	A causal linking word	*Does planning your activities help you do more? Participant4: It would probably help me to do more, we certainly used to plan more, because we did it in conjunction with friends...and you have to plan if you are organising, but otherwise...I am not a sitter around and apart from recently, when I watch television a lot, I would rather go out in a garden.*
(c+) Beliefs about Capabilities→ Behavioural Regulations	If-then statement	*(e) if I am way, and it is a weekend, and I am feeling fit, then I plan walks to do*
		I find it quicker and better to sit down and rest until it settles down [breathing], take my inhalers and then start again gently. I am guided by my body rather than to force my body to do thing
(d-) Beliefs about Capabilities→ Beliefs about Consequences	When-then statement	
(e-) Beliefs about Consequences → Reinforcement (f-) Beliefs about Capabilities→ Beliefs about consequences	A causal linking word	*'(d-) If I did more when I was quite asthmatic, by which I mean difficult to breath, it would make it worse.'*

'the asthma gets worse, partially because you are doing more, and causes you, (d-) I think that must cause a strain on the heart. (e-) So if you work backwards and try to stop the strain on the heart by not being so quite active, (f-) you will [then] feel better asthma-wise, and that might have a beneficial effect on the heart.'

'then I have noticed, my heart problem...And I had to live within that parameters really. You know I couldn't just ignore it, because I would have come to the full stop (f-). '

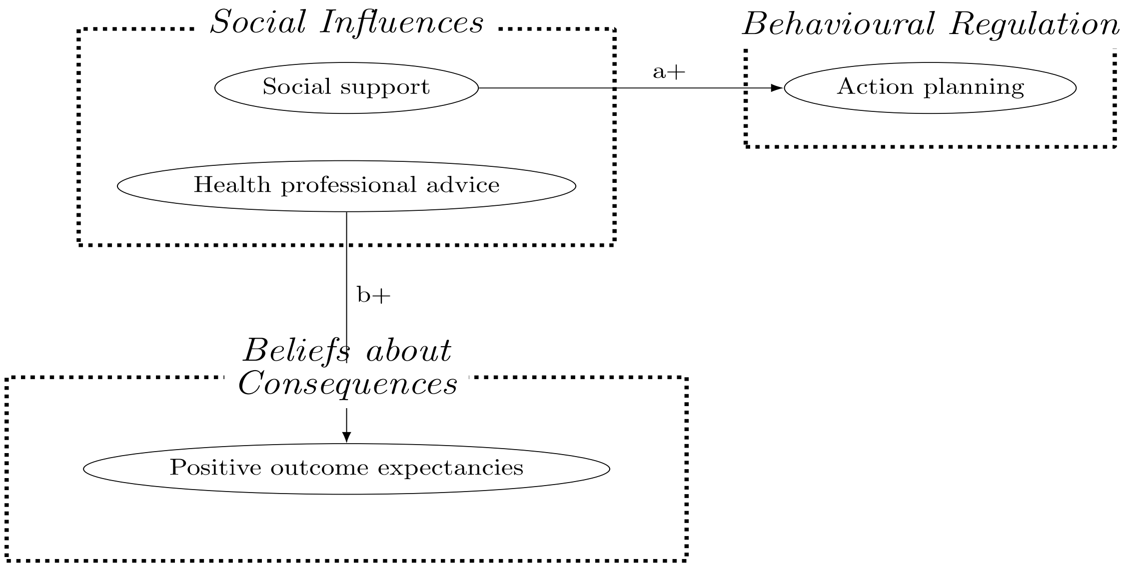
(g+) Beliefs about Capabilities Emotion	*If-then statement* *A causal linking word*	*I perhaps get a little bit depressed… If I can't do things, because of the asthma. I think that has been a problem...a lot of my life. It has prevented me...perhaps living a full life that I could have done. I just instinctively curtail my activities to suit that..*



Participant 4: The causal graph depicting perceived causal links induced by the lexico-syntactic patterns in this participant's transcript.

Participant 5: *Causal links among the TDF domains (and corresponding beliefs) evident from lexico-syntactic*

(a+) Social Influence Behavioural Regulation	Causal verbs	*No, sometimes I forget. Or there are other arrangements. I then try to do it another time. I keep a schedule…I write down how much I am ought to do this week, and then I tick it off…and when I see I have not done it today, I try to do it another time. My wife helps me to keep up with the schedule. Interviewer: Amazing! What does your wife say about these exercises or your activity in general? Participant5: she is the driving force of me doing all these, really. (laughs) She makes sure I do the exercise and the rest of it…*
(b+) Social Influences Beliefs about Consequences	Causal linking words	*It [exercise with step] will make me feel better and helps my condition. This is, frankly…this is why **** [HF-specialist nurse] suggests I do the exercise and the schedule.*

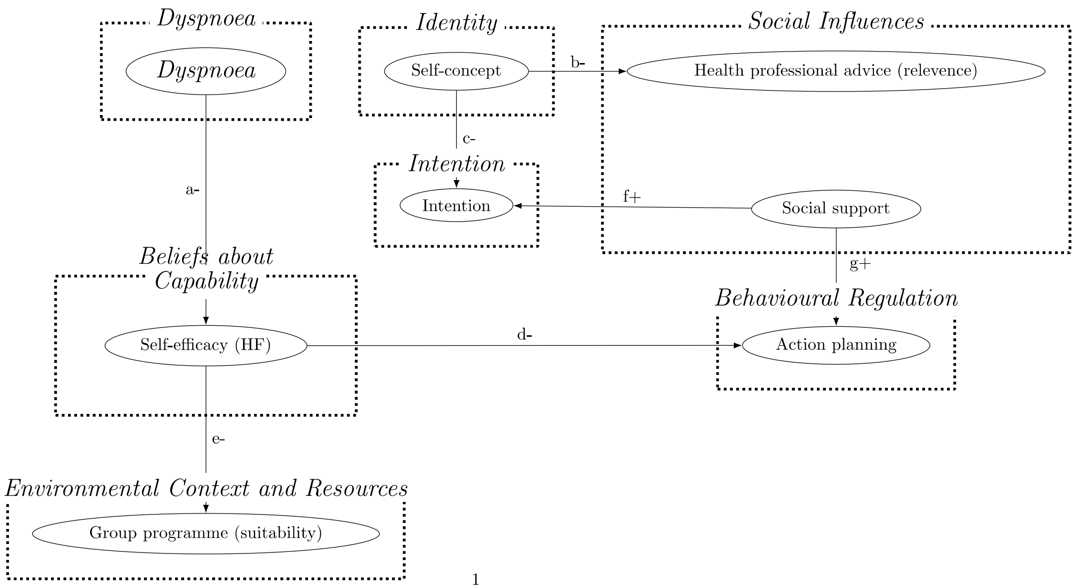


Participant 5: The causal graph depicting perceived causal links induced by the lexico-syntactic patterns in this participant's transcript.

Participant 6: *Causal links among the TDF domains (and corresponding beliefs) evident from lexico-syntactic*

(a+) Dyspnoea → Beliefs about Capabilities	Causal linking word	*Because I get breathless very quick and...We said about my blood pressure...there are lots of things, few things that i can't do now, some are related to age, and some are related to blood pressure.*
(b-) Social Professional Role and Identity → Social Influences	A counterfactual statement	*Well...when you go to these classes [exercise-based programme]: 'you should walk', and things like that...and yes, I agree with all that they say...and I would say 'yes' at the time, but that doesn't mean I [highlights I] to do it every day...I do agree with it, I, as a person, don't want to do it...but I feel I support them by saying: 'yes you should!', and I agree you should do it...but I don't do it...*
(c-) Social Professional Role and Identity → Intention	Causal linking words	*I know I should walk every day, but I don't... Interviewer: And why is that? Partcipant6: Why should I walk? Interviewer: Why you don't? Partcipant6: Because I am too lazy. I am a lazy person...I am a Leo, the lion. On the television it says the lion sleeps 18 hours a day and that's all I need [laughs].* *Let's start off with, I am a very lazy person: if i don't have to walk i won't walk, i will just sit in a chair...and eat chocolates (laughs). I have to push myself to walk…if i don't have to...because i love to read....and i am happiest when i am reading a nerd book. So, i would have to be strong willed, and make a time to get up and walk for half a mile*
(d-) Beliefs about Capabilities → Behavioural Regulation	A social counterfactual statement	*I am not a fan of getting up at 7 o'clock and running around Richmond Park. I know lots of people do and good luck to them. But it is not within me to do it.*
(e-) Beliefs about Capabilities → EC&R	A counterfactual statement	*I am a widow, and my husband passed...I go to *** [a bereavement social support group]...it is for people who have bereaving, and there are quite a few elderly people going...because you know, there partner has…passed away, they DO do walking sessions. All these energetic people who go...it is wonderful, and they go to Richmond park and they walk in there, and they walk there and there, they go to bushy parks, and they walk in there...and they walk by the Thames...all these places are near me...but they are striding out and doing this and...And then they are coming back...and I just couldn't walk that quickly or that far.*

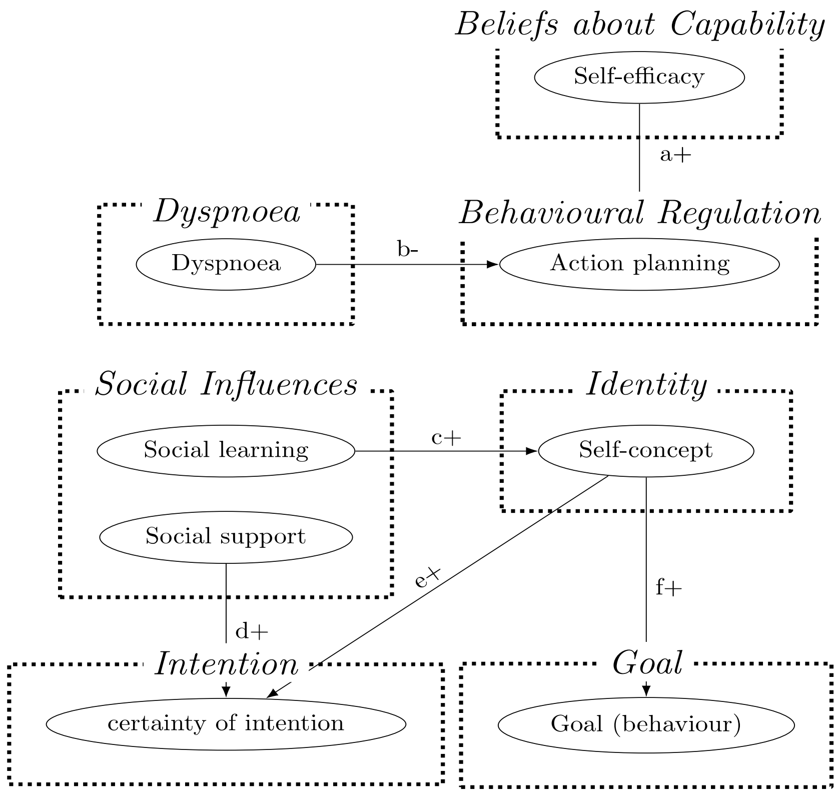
(f-) Social Influences ⊔ Intention	If-then statement	*if I had people, who were...going around on...erm...on...just walking really...or maybe the treadmill, you know people I know who are doing these things? I would, as a friend, I would join them, but I am not very good at going somewhere and getting on a treadmill and doing that for 10 or 15 minutes or whatever...and getting off and coming back home*
(g+) Social Influences ⊔ Behavioural Regulation	If-then statement	*As I am on my own, I would not make a plan...but if I was with other people, a friend and they exercised regularly, every Tuesday morning, and they asked me to join them*



Participant 6: The causal graph depicting perceived causal links induced by the lexico-syntactic patterns in this participant's transcript.

Participant 7: *The causal graph depicting perceived causal links induced by the lexico-syntactic patterns in this participant's transcript.*

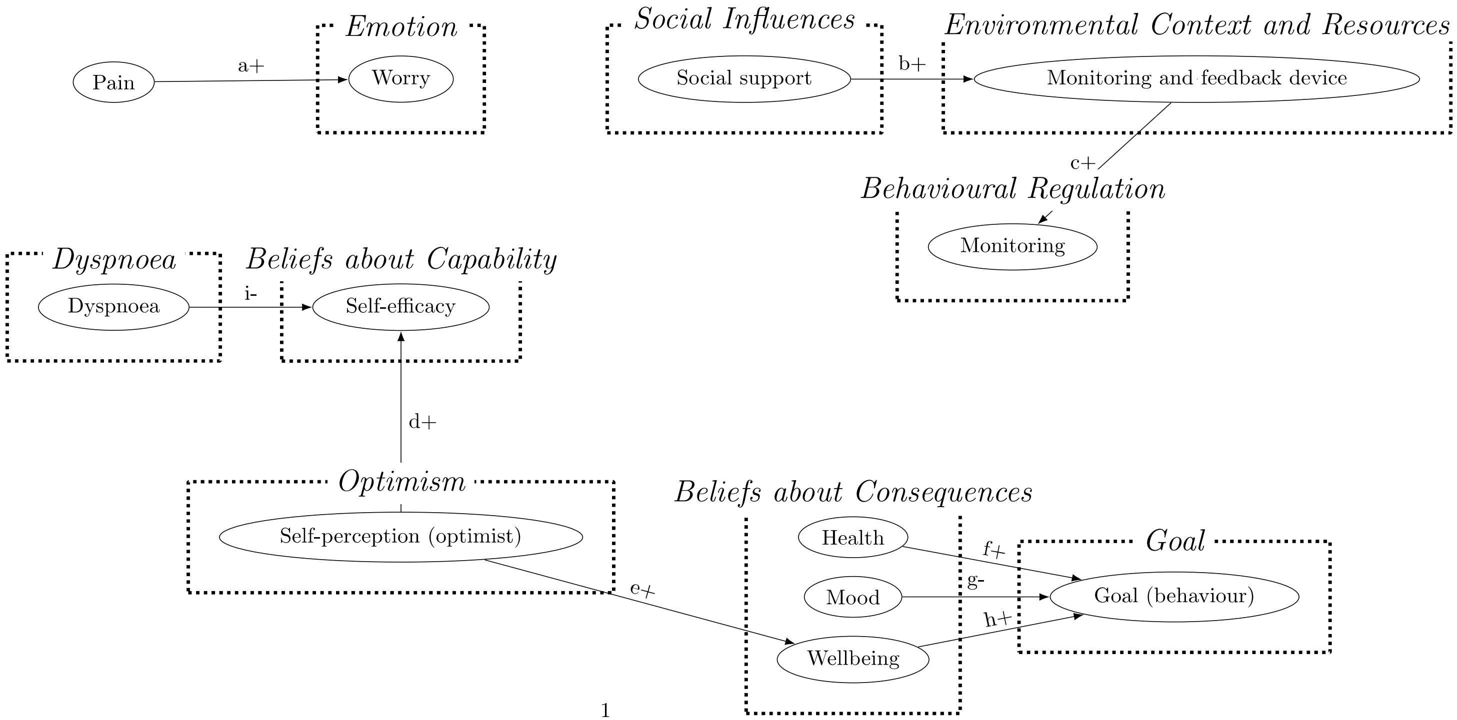
(a-)Beliefs about Capabilities → Behavioural Regulation	If-then statement	*I can do (get out of breath) at times during the day. If..I if I hurry too much. So I've learned how to pace myself.*
(b-) Dyspnoea → Behavioural Regulation	Counterfactual statement	*All right. I don't get any breathless at night. I can do at times during the day. If I if I hurry too much. So I've learned how to pace myself.*
(c+)Social Influences → Social Professional Role and Identity	Counterfactual statement	*It's [physical activity] a fairly big part [of my life]. You know, as I said, my parents were active, we were active, my daughter is now active and my granddaughter. Oh, we've always been an active family.*
(d+) Social Influences → Intention (and habit formation)	Counterfactual statement	*And I've always been active. My parents have always.. especially my mother, stressed the importance of being active, and to get out and do walking and everything. Yes. And I did it with my daughter… and my oldest, she does it with her daughter.*
(e+) Social Professional Role and Identity → Intention	Counterfactual statement	*Interviewer: That's fantastic! And how did you decide to do that [exercise routine]? Participant7: Well I suppose I'm...my family, they have always been active. I've always been active. So it's not something that happened suddenly.*
(f+) Social Professional Role and Identity → goal	Counterfactual statement	*Would you say that exercise is a priority? Participant7: It's part of... Like having a shower in the morning it's part of my life to exercise. Interviewer: OK. And how does mood affect it? Participant7: I don't know… because I've always done this.*
		I would feel wrong if I didn't do a certain amount of exercise every day it is part of my life, like eating.



Participant 7: The causal graph depicting perceived causal links induced by the lexico-syntactic patterns in this participant's transcript.

Participant 8: Causal links among the TDF domains (and corresponding beliefs) evident from lexico-syntactic patterns

(a-) *Pain* → *Emotion* (negative)	When-then statement	*Well, I get worried sometimes when I have pain. When the pain goes away I… you know… I'm back with my same feeling: 'positive man, happy man' and talking to the people.*
(b+) Social Influences → EC&R	A causal linking word	*I have Fitbit… it is five of us, my friend and family… I was the third to have this. My daughter and son got it later… so when I first heard about this, I was very happy to have one* once *they explained to me what this one does.*
(c+) EC&R → Behavioural Regulation	Counterfactual statement	*Interviewer: And before you got Fitbit did you do as much as you do now? Participant8: No…I did less…I still was doing it, but less. Especially I didn't have the record to see the results.*
(d+) Optimism → Beliefs about Capabilities	If-then statement	*Interviewer: Yes! And how confident are you in being physically active? Participant8: Very confident! I am a positive man!*
(e+) Optimism → Beliefs about Consequences	If-then statement	*I am a positive man, I like to be happy and I only .. I found …if I do this, I remain happy and you know it gives me…you know. Cheers me up, I don't have to..don't have to be sad, jobless or workless or ill in front of my children. When I do this I can remain happy and smiley and things like that.*
Beliefs about Consequences → Goal: (f+) Health (g+) Mood (h+) Wellbeing	If-then statement Causal verb, when-then statement Counterfactual statement	*[…] I found … (h+) If I do this, [then] I remain happy; and, you know, (g+) it gives me…you know, cheers me up, I don't have to..don't have to be sad, jobless or workless or (f+) ill in front of my children. When I do this I [then] can remain happy and smiley and things like that.*
(i-)Dyspnoea → Beliefs about Capabilities	If-then statement	*Oh, breathing! Then I shouldn't do it then. […] I feel tightness (points at chest), and I feel that I'm not fit for running, so I shouldn't run, then I go fast walking and I found it difficult as well. So no running; no fast walking…just normal walking.*

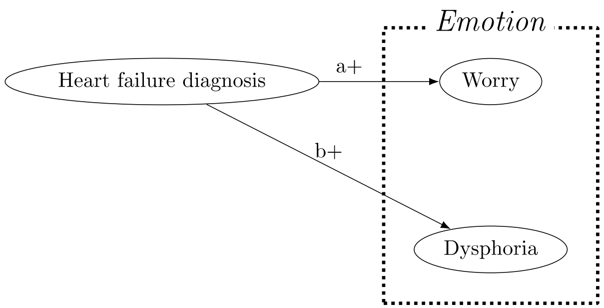


Participant 8: The causal graph depicting perceived causal links induced by the lexico-syntactic patterns in this participant's transcript

Participant 9: Causal links among the TDF domains (and corresponding beliefs) evident from lexico-syntactic patterns

HF diagnosis Emotion	A causal linking word

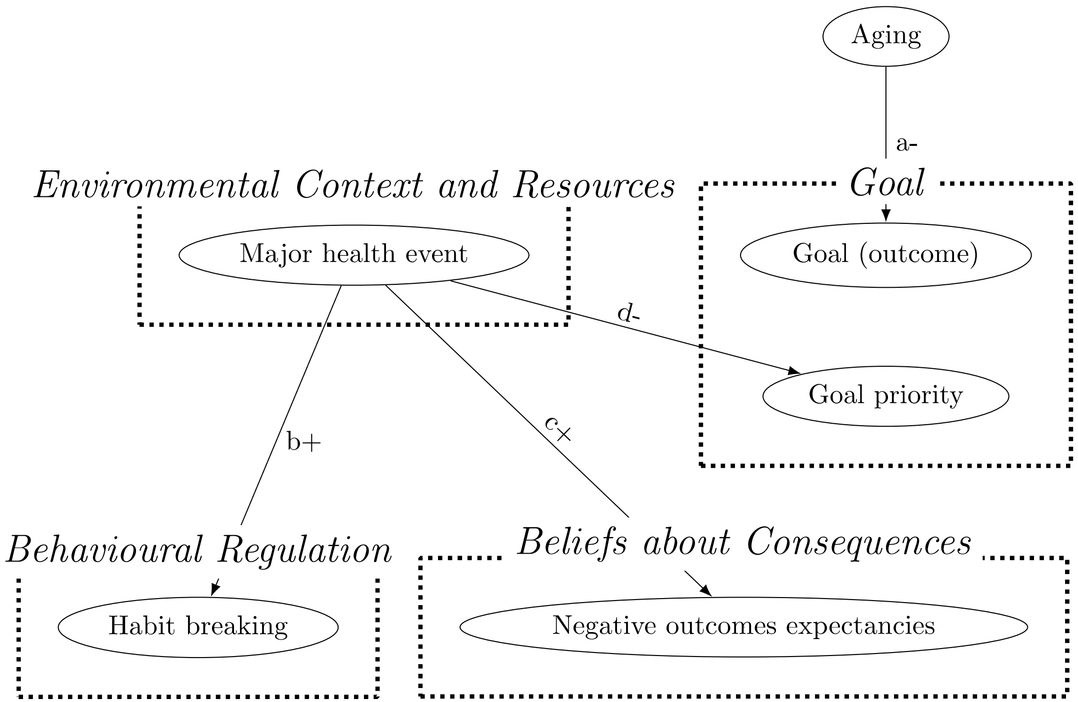
(b+) He [consultant] wrote a letter to my GP.. and ..wrote that I have HF. Since I read that letter I am very upset. I can't get up in the mornings…even my wife tells me: 'get up!' I can't get up.



Participant 9: The causal graph depicting perceived causal links induced by the lexico-syntactic patterns in this participant's transcript.

Participant 10: Causal links among the TDF domains (and corresponding beliefs) evident from lexico-syntactic patterns

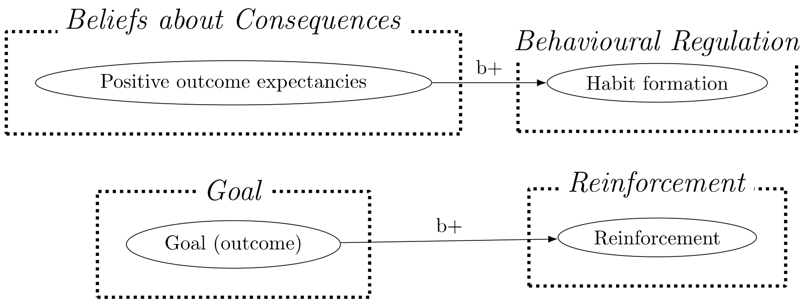
(a-) Ageing → Goal	A counterfactual statement	*Well, as you look at my thin arms and thin legs, it used to be full of muscles. You feel a wee bit of…not dejection exactly, but I'm fading away. No, not really. No benefits for me*
(b+) EC&R → Behavioural Regulation	A causal linking word	*I don't remember what it was, pacemaker probably. I don't remember. I remember being told to be careful [after a surgery] for a few months and not to do exercises as such. Once you get out of the habit, you …it is hard to start again…it is difficult to start again, because you forget.*
(d+) *EC&R → Goal*	A causal linking word	*Participant10: Well, yes… well, getting up and down the stools and doing various things I didn't see I would achieve anything really…. considering how well I was after my first time. After my first time for quite a few years, I could play golf…which is you are walking four or five miles…and hitting the ball far too many times (laughs) Interviewer: When did you feel that you had to do less when… when did it start? Participant10: When the pain started. After my first heart operation it lasted nearly 20 years the last year I probably had a heart attack. […]I am pretty certain I did. If they have to ask me and they look doubtful, maybe I didn't, maybe it was a severe angina attack… […]Well, that was…I am still a bit…angina…wee bit…I have chest pain, fundamentally that's angina…there is So yeah…no point punishing yourself so I stop.*
(c+) EC&R → Beliefs about Consequences	A counterfactual statement	*I am pretty certain I did [heave a heart attack]. If they have to ask me and they look doubtful, maybe I didn't, maybe it was a severe angina attack… Interviewer: I see, and after that event, you thought was a heart attack or severe angina…did you stop doing activities after that event? Participant10: Well, that was…I am still a bit…angina…wee bit…I have chest pain, fundamentally that's angina…there is So yeah…no point punishing yourself so I stop. Interviewer: So, there is no fear or worry about the symptoms, you just don't see a point? Participant10: Well, as I said, I want to go on…but why should I give myself a lot of pain…and put myself in danger, when stopping that would stop as well…if it kept on going. I suppose I would be ringing 999 and would be taken off to a hospital*



Participant 10: The causal graph depicting perceived causal links induced by the lexico-syntactic patterns in this participant's transcript.

Participant 11: Causal links among the TDF domains (and corresponding beliefs) evident from lexico-syntactic patterns

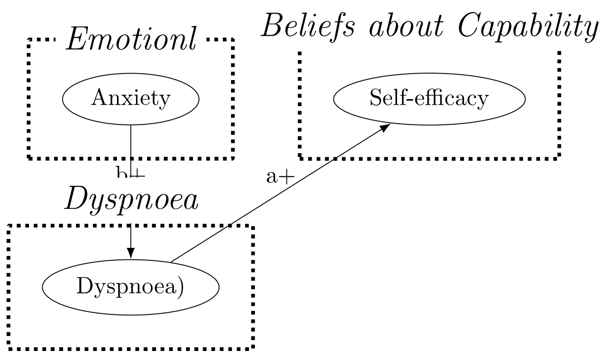
(a+) Beliefs about Consequences → Behavioural Regulation	A causal linking word	*It is just a regime in which I …it's just a habits and regime because I am aware that it keeps me fit.*
(b+) Goal → Reinforcement	If-then statement	*Yes, the rewards are that I stay a reasonably fit man…I enjoy them very much and look forward to the next holiday. Yeah. Interviewer: that's great would you say that - also one of the goals of exercises to stay independent? Participant11: Yeah, it is. It is enabling life, to be independent.*



Participant 11: The causal graph depicting perceived causal links induced by the lexico-syntactic patterns in this participant's transcript.

Participant 12: Causal links among the TDF domains (and corresponding beliefs) evident from lexico-syntactic patterns

Dyspnoea □ Beliefs about Capabilities	A counterfactual statement	*I get breathless. I mean I can walk up and down the stairs. I have a stair lift, but I have not used it recently, my condition has improved in that respect. I can climb up and down the stairs*
Emotion □ Dyspnoea	Causal linking word	*I think I am starting to get breathless now. I think it is because of anxiety*

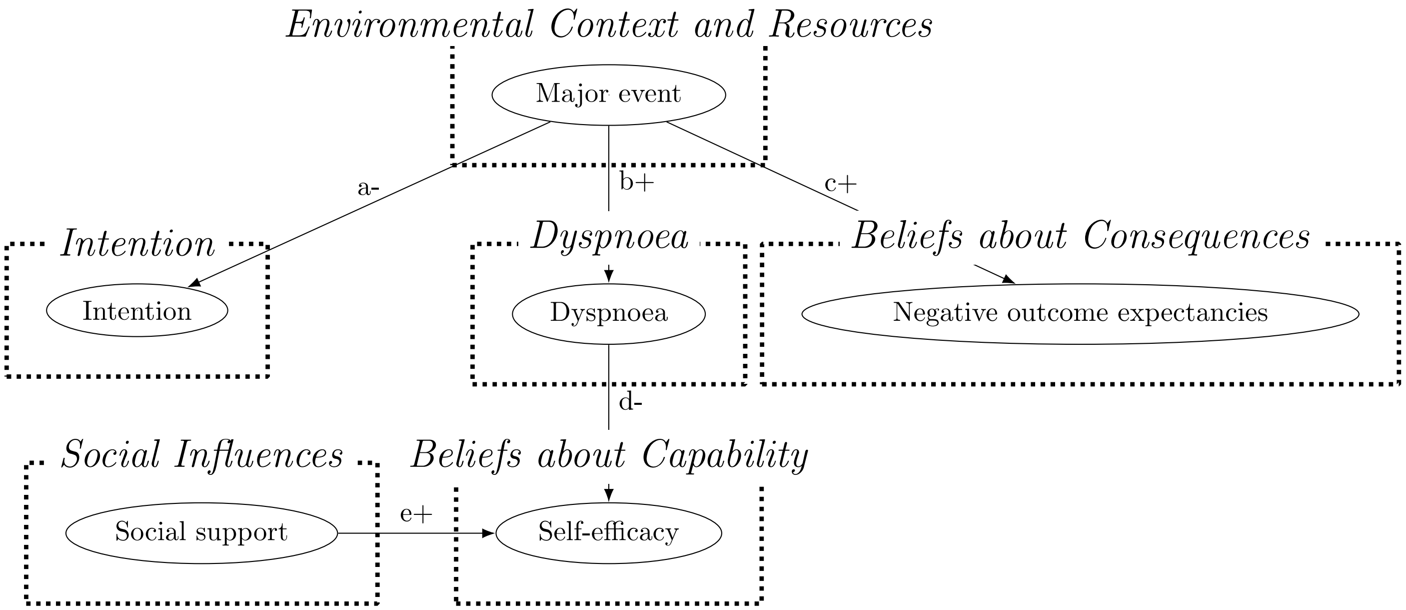


Participant 12: The causal graph depicting perceived causal links induced by the lexico-syntactic patterns in this participant's transcript.

Participant 13: Causal links among the TDF domains (and corresponding belief)s evident from lexico-syntactic patterns.

(a) EC&R Intention	When-then statement (until-then)	(a) *Interviewer: do you intend to do anything more or less do you intend to change your level of activity? Participant13: Until I get through this load of treatment. I highly doubt it... I can't really plan to do anything in particular apart from doing my normal chores*
(b, c) EC&R Beliefs about Consequences	When-then statement	*(b) It is not a nice feeling to be out of breath. (c) When I had ICD put in, I was taken away…I thought I was on my way out…it was scary…fortunately, the ambulance came in…So, I came to Royal Brompton by ambulance, and they decided I should have ICD and since then I was fine… Interviewer: So this sensation when you get out of breath, it reminds you of that event? Participant13: Yes, it is not a nice feeling…but when I use an inhaler…but this time last year it was happening every 20 yards, you can't take inhaler every 20 yards…that many times…you only take once so may hours*
(d) Dyspnoea Beliefs about Capabilities	When-then statement Causal linking word	*(d-) The desire to go and do something is there I don't have the energy to do whatever it is. I mean I can set myself a goal and I will walk go from here to Chelsea but I would have to stop several times .no, I'm much better now than I was earlier in the year and my friend I have a friend at the society I work for when we use to go shopping around about Christmas time and that I could only walk about 20 yards before I had to sit down and I'm much better now my breathing is much better now… that's good but I mean when you can only work 20 hours with and having to sit down because you really can't go any further it is it's terribly frustrating and exhausting so she [daughter] noticed the difference in breathing she said I don't have to. Now I can walk without having to sit down…*
(e) Social Influences Beliefs about Capabilities	A counterfactual statement Causal linking word	*Due to the perceived lack of ability, Participant 13 held a negative outcome expectancy that she will need to sit out and would not risk walking far distances without knowing that there will be an opportunity to take a break. With social support of her daughter she felt enabled to walk further, as negative outcome expectancies were removed:* *I go to a bus stop and I think to myself it would be very nice if I could walk to the next bus stop but I am not absolutely convinced I can do that without having to sit down for quite a while. Now, another day I went with my daughter to an appointment – I had an appointment in the morning at *** hospital, after having an appointment in *** in a hospital. […] Since my daughter was there, we could walk from *** to *** and we did [the distance between the hospitals is 0.8 to one mile if walking]. And I didn't sit down once, and there was the bus stops. So, that was quite a long way, that was the furthest I walked in several months.*

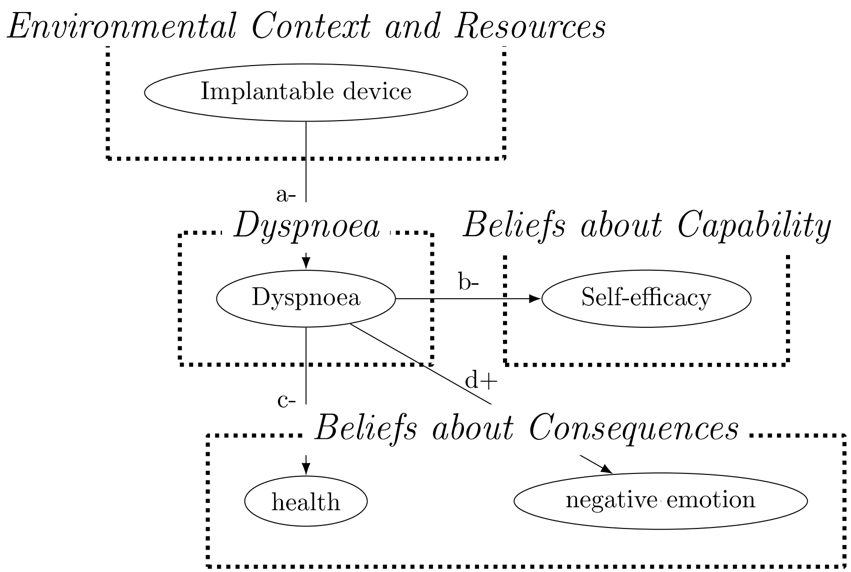
When I am with my daughter, I am less nervous and I am able to walk further… because she was there…and I walked very slowly but I did walk all the way and I was very pleased with myself, because I felt I have achieved something.



Participant 13: The causal graph depicting perceived causal links induced by the lexico-syntactic patterns in this participant's transcript.

Participant 14: Causal links among the TDF domains (and corresponding beliefs) evident from lexico-syntactic patterns

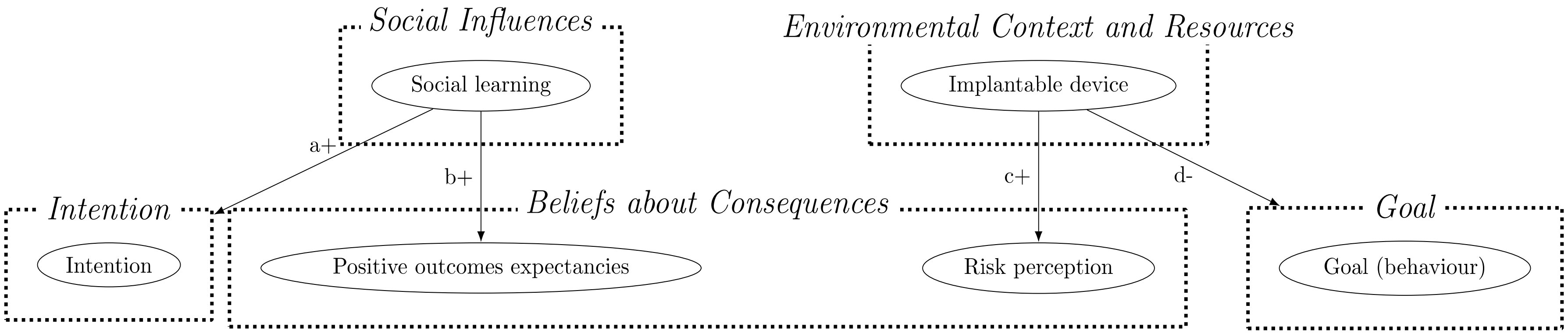
(a-) EC&R → *Dyspnoea*	If-then statement	*No. I am not exercising at the moment purely because it is making me out of breadth. But, on the other hand, if I had a pacemaker fitted, and it makes a difference, and I am less out of breath, then I will actually do more walking and exercise.*
(b-) Dyspnoea → Beliefs about Capabilities	Since linking word	*No, it is breathlessness. If it was not for breathlessness I would walk more than I do. I used to walk more than I do now. Since I got this extreme breathlessness I can't.*
Dyspnoea → Beliefs about Consequences: (c-) feeling ill (health) (d+) negative emotion	If-then statement Causal verbs	*If I can avoid feeling breathless then I will , (d-) I don't enjoy it, (c-) it makes me feel ill* *If I have a pacemaker and if I have a bit more breath, I should be able to do more and that would improve my life in general.*



Participant 14: The causal graph depicting perceived causal links induced by the lexico-syntactic patterns in this participant's transcript.

Participant 15: Causal links among the TDF domains (and corresponding beliefs) evident from lexico-syntactic patterns

(a+) Social Influences → Intention (b+) Social Influences → Beliefs about Consequences	A counterfactual statement	(a) *Older friends..they are marvellous in so many ways, and they had to get on with life. When I got to their age....I learnt from them: you got to do your best.* *As I tell my friend next door, he has dementia, he doesn't remember things as much… he used to come to play bowls with me, about 2 years ago he stopped. And he had hip replacement. Some people like that they gave up. (b+) I have other friends who did not give up and they do not have a lot of medical problems. So, I learnt from them – (a+) you got to try and do your best, as much as you can.*
(c+)EC&R → Beliefs about Consequences (d-) EC&R → Goal	If-then statement	(c)*Well, partially, because of the wires that are connected to the heart…if you overdo it [then] you can end up in hospital*



Participant 15: The causal graph depicting perceived causal links induced by the lexico-syntactic patterns in this participant's transcript.

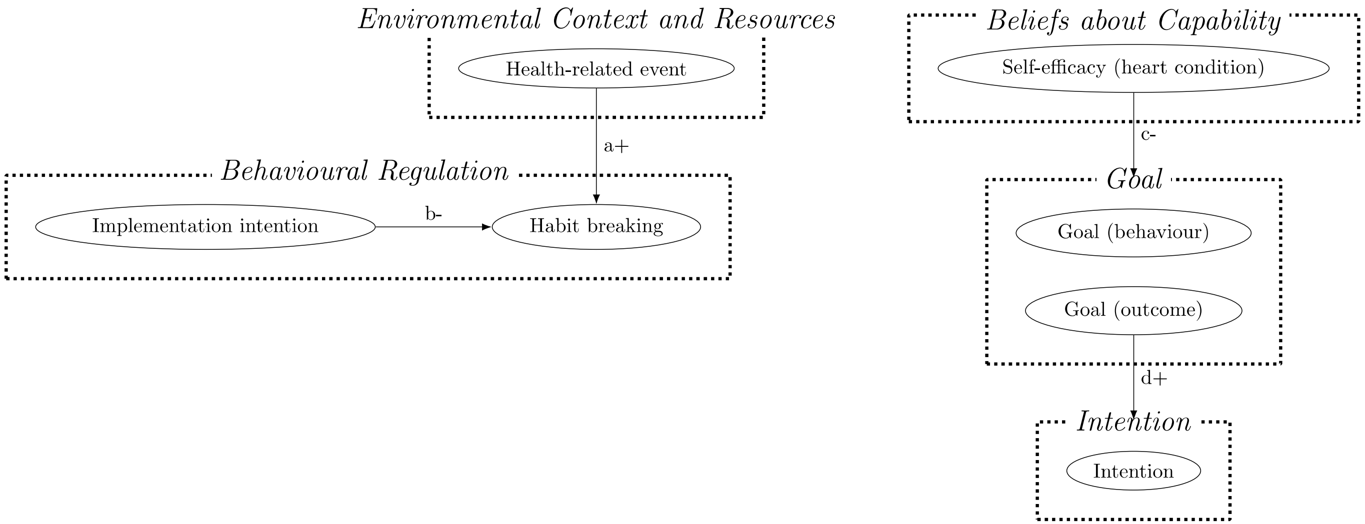
Participant 16: Causal links among the TDF domains (and corresponding beliefs) evident from lexico-patterns.

(a+) EC&R → Behavioural Regulation	When-then statement	*I used to exercise before but when I had my valve operation here I was told to avoid this kind of exercise because it it didn't help while I was going through that... so, it's been some time since I had a regular exercise regime*
(b-) *Behavioural Regulation* (Implementation Intention → Habit breaking)	A counterfactual statement	*I tried to keep it going, because you must have some sort of discipline to keep it going, otherwise you just stop. I don't have a plan but I try to make sure that I don't miss too many*
(c-) Beliefs about Capabilities → Goal	If-then statement	The awareness of physical limits caused the participant to reduce their behavioural Goal: *[…]as I've explained it, do it [physical activity] to a certain limit but don't exhaust yourself because then you know if your heart isn't working at full strength, which it is not, that is something you have to adjust for and you can feel it.* The behavioural goal was regulated in accordance with somatic feedback as described below: *You could feel it if you were overdoing it.*
(d+) Goal → Intention	A counterfactual statement	In contrast, Goal (outcome) such as enjoying life to the fullest, promoted physical activity and was causally linked to strong *Intention* to engage in physical activity: *Yes, you can't enjoy life if you are not fit. At least you can't enjoy to its fullest […] And that's another reason to get fit you can't write [Participant 1 writes an autobiography] unless you are fit. If you*

unfit you can't do anything... or photographs.

Another important Goal (outcome) linked to Intention was avoiding feeling helpless and regaining independence:

Well, nobody wants to feel helpless, […] when it's difficult to move properly, you do desperately feel the need for fitness when you walk and your hips hurt because, because your legs aren't properly toned, the muscles have gone. So, you've got to rebuild everything. And at the senior age..I am.. it takes longer but I want to do it



Participant 16: The causal graph depicting perceived causal links induced by the lexico-syntactic patterns in this participant's transcript.

Appendix S. Assessment of the validity of the findings (Creswell et al., 2000)

Validity	**Reflexivity and reflection on researcher's values, assumptions, and potential biases.** *Reflective journal was maintained throughout data collection, data analysis and write up.* *Supervisor debriefing to assist the researchers' processes (uncover biases (attention, sense making) or assumptions)* *reliability of the coding (inter-rater reliability)* *coding strategy across interviews to ensure systematic analysis* *Representativeness of the findings in relation to the context:* *The sample of 16 HF patients managed in an outpatient clinic;* *Semi-structured audio recordings were revisited to check that emerging themes remain representative of participants' accounts of physical activity model;* *Use of rich and thick verbatim from participants' to a) ensure it is about physical activity b) representative of their accounts;* *Participants were invited to comment on the research findings and themes (pending)*
Consistency	**Transparency** *Quality of the study reporting;* *maintaining a research diary documenting challenges and issues assisted in maintaining consistency between the study's aim, methods, analysis and reporting;* *Emerging themes discussed with research team members who have research expertise in HF and behaviour change where assumptions could be challenged and consensus reached*
Applicability	**Application of findings to other contexts**: Rich detail of context Application to further investigation (in Phase 2)

Appendix T. Letter of Health Research Authority approval.

NHS
Health Research Authority

Professor Stanton Newman
Centre for Health Services Research School of Health Sciences, City University London
Myddleton Street Building
London
EC1R 1UW

Email: hra.approval@nhs.net

08 June 2017

Dear Professor Newman

Letter of HRA Approval

Study title:	**Factors influencing physical activity among individuals living with heart failure: a mixed-methods study.**
IRAS project ID:	**205050**
REC reference:	**17/EE/0183**
Sponsor	**City University of London**

I am pleased to confirm that **HRA Approval** has been given for the above referenced study, on the basis described in the application form, protocol, supporting documentation and any clarifications noted in this letter.

Participation of NHS Organisations in England

The sponsor should now provide a copy of this letter to all participating NHS organisations in England.

Appendix B provides important information for sponsors and participating NHS organisations in England for arranging and confirming capacity and capability. Please read ***Appendix B*** **carefully**, in particular the following sections:

- *Participating NHS organisations in England* – this clarifies the types of participating organisations in the study and whether or not all organisations will be undertaking the same activities
- *Confirmation of capacity and capability* - this confirms whether or not each type of participating NHS organisation in England is expected to give formal confirmation of capacity and capability. Where formal confirmation is not expected, the section also provides details on the time limit given to participating organisations to opt out of the study, or request additional time, before their participation is assumed.
- *Allocation of responsibilities and rights are agreed and documented (4.1 of HRA assessment criteria)* - this provides detail on the form of agreement to be used in the study to confirm capacity and capability, where applicable.

Further information on funding, HR processes, and compliance with HRA criteria and standards is also provided.

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NHS

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Miss Aliya Amirova

City University of London Northampton Square London
EC1V 0HB

Dear Aliya,

Employer: Accountable to:

City University of London Stanton Newman/Tracy Kitto

This letter confirms your right of access to conduct research through the trust(s) identified in the box below, for the purpose and under the terms and conditions set out in page 2 & page 3.

28 October 2019

Study Title: study R&D reference: REC reference: Factors influencing physical activity among individuals living with heart failure: a mixed methods 205050 17/EE/0183		
Letter of access duration:	Start date: 28/10/2019	End date: 12/03/2020
East London NHS Foundation Trust - -		
If any information on this document is altered after the date of issue, this document will be deemed INVALID		

Yours sincerely,

Mabel Saili
Research & Development Manager

LOA-AA
It is the researcher's responsibility to provide their substantive employer with a copy of this document

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You have a right of access to conduct such research as confirmed in writing in the letter of permission for research from this NHS organisation. Please note that you cannot start the research until the Principal Investigator for the research project has received a letter from us giving permission to conduct the project.

The information supplied about your role in research at relevant trust(s) has been reviewed and you do not require an honorary research contract with this NHS organisation. We are satisfied that such pre-engagement checks as we consider necessary have been carried out.

You are considered to be a legal visitor to relevant trust(s) premises. You are not entitled to any form of payment or access to other benefits provided by this NHS organisation to employees and this letter does not give rise to any other relationship between you and this NHS organisation, in particular that of an employee.

While undertaking research through the relevant trust(s), you will remain accountable to your employer but you are required to follow the reasonable instructions of Angela Williams, Head of Research & Development Noclor in this NHS organisation or those given on her/his behalf in relation to the terms of this right of access.

Where any third party claim is made, whether or not legal proceedings are issued, arising out of or in connection with your right of access, you are required to co-operate fully with any investigation by this NHS organisation in connection with any such claim and to give all such assistance as may reasonably be required regarding the conduct of any legal proceedings.

You must act in accordance the relevant trust(s) policies and procedures, which are available to you upon request, and the Research Governance Framework.

You are required to co-operate with relevant trust(s) in discharging its duties under the Health and Safety at Work etc Act 1974 and other health and safety legislation and to take reasonable care for the health and safety of yourself and others while on relevant trust(s) premises. You must observe the same standards of care and propriety in dealing with patients, staff, visitors, equipment and premises as is expected of any other contract holder and you must act appropriately, responsibly and professionally at all times.

If you have a physical or mental health condition or disability which may affect your research role and which might require special adjustments to your role, if you have not already done so, you must notify your employer and the Trust relevant trust(s) prior to commencing your research role at the Trust.

You are required to ensure that all information regarding patients or staff remains secure and strictly confidential at all times. You must ensure that you understand and comply with the requirements of the NHS Confidentiality Code of Practice and the Data Protection Act 2018. Furthermore you should be aware that under the Act, unauthorised disclosure of information is an offence and such disclosures may lead to prosecution.

You should ensure that, where you are issued with an identity or security card, a bleep number, email or library account, keys or protective clothing, these are returned upon termination of this arrangement. Please also ensure that while on the premises you wear your ID badge at all times, or are able to prove your identity if challenged. Please note that this NHS organisation accepts no responsibility for damage to or loss of personal property.

We may terminate your right to attend at any time either by giving seven days' written notice to you or immediately without any notice if you are in breach of any of the terms or conditions described in this letter or if you commit any act that we reasonably consider to amount to serious misconduct or to be disruptive and/or

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prejudicial to the interests and/or business of this NHS organisation or if you are convicted of any criminal offence. You must not undertake regulated activity if you are barred from such work. If you are barred from working with adults or children this letter of access is immediately terminated. Your employer will immediately withdraw you from undertaking this or any other regulated activity and you MUST stop undertaking any regulated activity immediately.

Your substantive employer is responsible for your conduct during this research project and may in the circumstances described above instigate disciplinary action against you.

The relevant trust(s) above will not indemnify you against any liability incurred as a result of any breach of confidentiality or breach of the Data Protection Act 2018. Any breach of the Data Protection Act 2018 may result in legal action against you and/or your substantive employer

If your current role or involvement in research changes, or any of the information provided in your Research Passport changes, you must inform your employer through their normal procedures. You must also inform your nominated manager in this NHS organisation.

Project ID number: 205050
Version: 3.0
Date: 06 February 2019
REC reference: 17/EE/0183
Title of Project: Factors influencing physical activity in heart failure
Name of Researcher: Aliya Amirova

Physical activity in heart failure

We would like to invite you to take part in a research study. Before you decide whether you would like to take part it is important for you to understand why this study is being conducted and what it would involve. Please take time to read the information below, and feel free to discuss this with others if you wish. Please feel free to ask us for more information about the study.

1. What is the purpose of this study?

The study aims to investigate what helps or prevents people with heart failure in being physically active. Currently, there is little research on this topic. We hope that this research will help to develop a programme supporting individuals who have heart failure.

2. Why have I been invited to take part?

You have been invited to take part in this study because you have been diagnosed with heart failure. We are hoping to recruit approximately 166 people for this study.

3. Do I need to be physically active to take part?

No, we are not asking you to change your usual physical activity level.

4. Do I have to take part?

It is up to you to decide whether or not to take part. If you do decide to take part you will be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason.

If you decide to take part please keep this information sheet and feel free to ask any questions at any point. You are free to withdraw from the study at any time. Please be advised that deciding to not take part or withdrawing your participation will not change the care provided to you.

5. What happens if I agree to take part?

If you decide to take part in the study, you will be asked to complete a questionnaire about physical activity. The questionnaire takes around 25 minutes and you can complete it in the clinic, by phone or online, whichever you prefer. You will be shown how to use an activity tracker and how to complete a physical activity log. You then will be asked to wear an activity tracker like the one in the picture below for 7 days in a row. If, for any reason, you do not wish to wear the activity tracker, we would still welcome your participation in the study and you are invited to complete the baseline questionnaire and the activity log.

The activity tracker is worn on the wrist and does not need to be charged. It can be worn in the shower, but would need to be taken off if you go swimming or take a bath. This type of tracker has been previously used for research purposes at Royal Brompton & Harefield NHS Foundation Trust.

Source: http://actigraphcorp.com/products/actigraph-link/

Throughout the same 7-day period you will be asked to keep a log of your activities during each day. Completing the physical activity log takes around 15 minutes.

At the end of the 7 days, the researcher will meet you at a place and time convenient to you and will collect the physical activity log and tracker from you.

We will need your permission to access your medical records which directly relate to this study, this will include: how long you have had heart failure, its severity, other illnesses, how often and for how long you have been hospitalised in the last year, and your medication. The information you provide will be kept strictly confidential and only the researcher will see the identifiable records.

6. What do I have to do?

You will be asked to:

- Fill in a questionnaire about what may influence your physical activity.
- Wear an activity tracker
- Complete a physical activity log every day for 7 days.
- Give back the tracker and physical activity log to the researcher after the 7-day period.
- Carry on with your daily life as usual.

7. What are the possible benefits of taking part?

There are no immediate personal benefits of taking part. However, we hope that the information you provide will help to develop an appropriate programme to support individuals with heart failure and help them to be more physically active.

8. What are the possible risks of taking part?

Please inform the researcher if you have been advised to not engage in any physical activity by any health professional. We are not aware of any risks involved in taking part to those who are not advised to restrain from physical activity. The study does not involve any changes to your health care. We do not expect the tracker to cause any problems, however, if you find wearing an activity tracker to cause any discomfort please feel free to stop and inform the research team.

9. Can I withdraw from the study?

You can withdraw from this study at any point without providing any reason for doing so. Your decision will not have a bearing on the health care you receive.

10. What happens if I don't want to carry on with the study?

If you decide at any point to withdraw from the study, you can inform the researcher about this decision by phone (+44 (0) 7947372732) or email aliya.amirova@city.ac.uk. If you would like the information you have given to be destroyed, this can also be arranged with the researcher.

11. What can I do to take part in the study?

If you would like to take part in this study please let a member of your clinical team know when you attend your next clinic appointment. They will introduce you to a member of the research team.

12. Will my taking part in the study be kept confidential?

Any information you share with us will be kept strictly confidential, will be handled securely, and will be used for the research purposes of this study only. We will use a unique number on all records, rather than your own name. Study information will be securely stored in locked files or on a password-protected computer at City, University of London. Only authorised individuals directly involved with the study will have access to the data.

City, University of London will collect information about you for this research study from Royal Brompton NHS Trust/East London NHS Trust. This information will include your name, and health information, which is regarded as a special category of information. We will use this information for the purposes of the study described on the first page of this Information Sheet.

13. What happens to the information I provide?

The information you provide will be anonymously reported at the meetings with the research team, in professional publications as well as in a thesis written for submission to City, University of London. You will not be identified in any reports or publications. If you would like to be sent a full summary of the results at the end of the study please let the researcher know.

14. Who are the organisers of the research study?

The organisers of this study are researchers at the School of Health Sciences, City, University of London.

15. What will happen if there is a problem?

If you have any problems, concerns or questions about this study, you should ask to speak to a member of the research team. If you remain unhappy and wish to complain formally, you can do this through the University complaints procedure. To complain about the study, you need to phone 020 7040 3040. You can then ask to speak to the Secretary to Senate Research Ethics Committee and inform them that the name of the project is: Physical activity in heart failure.

You could also write to the Secretary at:
Anna Ramberg
Secretary to Senate Research Ethics Committee
Research Office, E214
City, University of London
Northampton Square
London
EC1V 0HB
Email: Anna.Ramberg.1@city.ac.uk

City, University of London holds insurance policies, which apply to this study. If you feel you have been harmed or injured by taking part in this study you may be eligible to claim compensation. This does not affect your legal rights to seek compensation. If you are harmed due to someone's negligence, then you may have grounds for legal action.

16. Who has reviewed the study?

This study has been reviewed by the East of England – Cambridge Central Research Ethics Committee, NHS. This project has been approved by the Health Research Authority, UK [17/EE/0183].

17. Can I request a report of the study findings?

If you are interested in the findings of the study, you can ask the research team to send you a report. Please do let us know using contact details provided below. Please be aware that it will take some time before any reports can be published.

18. Further information and contact details:

If you would like to discuss the study please feel free to contact the research team:

Aliya Amirova

Contact details: Aliya.amirova@city.ac.uk; +44(0) 7947372732

Dr Kathleen Mulligan

Contact details: Kathleen.Mulligan.1@city.ac.uk; +44 (0)20 7040 0889

Dr Shashi Hirani

Contact details: Shashi.Hirani.1@city.ac.uk; +44 (0) 207 040 0880

Postal address: Centre for Health Services Research, School of Health Sciences, City University London, Northampton Square, London, EC1V 0HB

Data Protection Privacy Notice: What are my rights under the data protection legislation?

City, University of London is the data controller for the personal data collected for this research project. Your personal data will be processed for the purposes outlined in this notice. The legal basis for processing your personal data will be that this research is a task in the public interest, that is City, University of London considers the lawful basis for processing personal data to fall under Article 6(1)(e) of GDPR (public task) as the processing of research participant data is necessary for learning and teaching purposes and all research with human participants by staff and students has to be scrutinised and approved by one of City's Research Ethics Committees.

Further, City considers the processing of special category personal data will fall under Article 9(2)(g) of the GDPR as the processing of special category data has to be for the public interest in order to receive research ethics approval and occurs on the basis of law that is, inter alia, proportionate to the aim pursued and protects the rights of data subjects.

The rights you have under the data protection legislation are listed below, but not all of the rights will apply to the personal data collected in each research project:

*right to be informed
*right of access
*right to rectification
*right to erasure
*right to restrict processing
*right to object to data processing
*right to data portability
*right to object
*rights in relation to automated decision making and profiling

For more information, please visit www.city.ac.uk/about/city-information/legal

What if I have concerns about how my personal data will be used after I have participated in the research?

In the first instance you should raise any concerns with the research team, but if you are dissatisfied with the response, you may contact the Information Compliance Team at dataprotection@city.ac.uk or phone 0207 040 4000, who will liaise with City's Data Protection Officer Dr William Jordan to answer your query.

If you are dissatisfied with City's response you may also complain to the Information Commissioner's Office at www.ico.org.uk

Thank you for taking the time to read this information.

Appendix W. Consent form: the quantitative study

Please initial box

1. I confirm that I have read the information sheet dated................... (version...........) for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.	
2. I understand that taking part in the study will involve: ● Filling in a questionnaire about physical activity ● Keeping a log of my activities for 7 consecutive days.	
3. I understand that taking part in the study will involve: Wearing an activity tracker for 7 consecutive days.	
4. I understand that data being collected relates to part of a research study about physical activity in people who have heart failure. As a result City, University of London is responsible for my personal information which will include data relating to my health, age, sex, level of education, ethnicity, marital and occupational status, aetiology, diagnosis duration, New York Heart Association Class, Left Ventricular Ejection Fraction (%), hospitalisation (frequency and duration in the past year), medication, comorbidities, frailty levels, barriers and enablers of physical activity, and physical activity levels.]. This research is necessary for learning and teaching purposes and therefore processing of personal data is covered under the General Data Protection Regulation (GDPR).	
5. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my medical care or legal rights being affected.	
6. I understand that any information I provide will be treated as confidential.	
7. I understand that relevant sections of my medical notes and data collected during the study may be looked at by individuals from City, University of London, from regulatory authorities or from the NHS Trust, where it is relevant to my taking part in this research. I give permission for the research team to have access to my records.	
8. I agree to City recording and processing this information about me. I understand that this information will be used only for the purpose(s) set out in this statement and my consent is conditional on City complying with its duties and obligations under the General Data Protection Regulation (GDPR).	
9. I give my permission for the data I provide to be stored at City, University of London secure storage facility for 10 years after study completion, and securely disposed of thereafter.	
10. I would like the results of the study to be shared with me.	

11.	I agree to take part in the above study.	

Name of Participant	Signature	Date
Name of Researcher	Signature	Date

When completed: 1 for participant; 1 for researcher site file; 1 (original) to be kept in medical notes.

Aliya Amirova
Contact details: Aliya.amirova@city.ac.uk; 020 7040 0871; 07816284278

Appendix X. Physical activity log

Dear Participant,

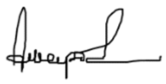
Thank you for agreeing to take part in this study.

This research study, conducted at City University of London investigates factors that may influence your physical activity. Therefore, you are being asked to complete this physical activity log (below) for 7 consecutive days. The log describes your everyday activities and takes around 10 minutes to be completed. You will be shown how to complete the physical activity log by the researcher.

At the end of the 7 days, the researcher will meet you at a place and time convenient to you and will collect the physical activity log.

If you decide to withdraw your participation, please feel free to do so at any point. If you have any questions about the log or the study please contact Aliya Amirova.
e-mail: aliya.amirova@city.ac.uk
phone: 020 7040 0871; 07816284278

Thank you!
Aliya



Participant Study Number:

Study group:

Date:

D	D	M	M	M	Y	Y	Y	Y

Activity	Did you do the activity today? *(Please circle below)*		At what effort?			How many times ?	Start time *(please enter timing for all occasions you did the activity)*	End time
Home activities								
cleaning, sweeping carpet or floors, vacuuming	YES	NO	Light	Moderate	High			
multiple household tasks all at once	YES	NO	Light	Moderate	High			
cooking, washing dishes, cleaning up	YES	NO	Light	Moderate	High			
groceries shopping	YES	NO	Light	Moderate	High			
carrying groceries upstairs	YES	NO	Light	Moderate	High			
ironing	YES	NO	Light	Moderate	High			
D.Y.I activities	YES	NO	Light	Moderate	High			
gardening	YES	NO	Light	Moderate	High			
child care	YES	NO	Light	Moderate	High			
dusting	YES	NO	Light	Moderate	High			
Other:								

Exercise								
bicycling	YES	NO	Light	Moderate	High			
push-ups, sit-ups, pull-ups	YES	NO	Light	Moderate	High			
weight lifting	YES	NO	Light	Moderate	High			
treadmill	YES	NO	Light	Moderate	High			
rope skipping	YES	NO	Light	Moderate	High			
rowing	YES	NO	Light	Moderate	High			
stretching	YES	NO	Light	Moderate	High			
yoga	YES	NO	Light	Moderate	High			
dance	YES	NO	Light	Moderate	High			
callisthenic, gymnastics	YES	NO	Light	Moderate	High			
Pilates	YES	NO	Light	Moderate	High			
martial arts (Judo, karate, tai chi)	YES	NO	Light	Moderate	High			
running	YES	NO	Light	Moderate	High			
swimming	YES	NO	Light	Moderate	High			
walking for exercise	YES	NO	Light	Moderate	High			
Other:	YES	NO	Light	Moderate	High			

Leisure activities								
bowling (10 pin)	YES	NO	Light	Moderate	High			
bowling (lawn green)	YES	NO	Light	Moderate	High			
general dancing	YES	NO	Light	Moderate	High			
golf	YES	NO	Light	Moderate	High			
fishing	YES	NO	Light	Moderate	High			
table tennis	YES	NO	Light	Moderate	High			
walking for pleasure or socially	YES	NO	Light	Moderate	High			
pool/Snooker	YES	NO	Light	Moderate	High			
playing with children	YES	NO	Light	Moderate	High			
religious activities	YES	NO	Light	Moderate	High			
sexual activities	YES	NO	Light	Moderate	High			
Sports								
archery	YES	NO	Light	Moderate	High			
squash	YES	NO	Light	Moderate	High			
netball	YES	NO	Light	Moderate	High			
softball, rounders’	YES	NO	Light	Moderate	High			
boxing	YES	NO	Light	Moderate	High			
cricket	YES	NO	Light	Moderate	High			
curling	YES	NO	Light	Moderate	High			
darts	YES	NO	Light	Moderate	High			
tennis	YES	NO	Light	Moderate	High			
football	YES	NO	Light	Moderate	High			
Frisbee	YES	NO	Light	Moderate	High			

hockey	YES	NO	Light	Moderate	High			
ice or roller skating	YES	NO	Light	Moderate	High			
lacrosse	YES	NO	Light	Moderate	High			
rugby	YES	NO	Light	Moderate	High			
volleyball	YES	NO	Light	Moderate	High			
Other:	YES	NO	Light	Moderate	High			
Self-care								
getting ready for bed	YES	NO	Light	Moderate	High			
bathing	YES	NO	Light	Moderate	High			
dressing	YES	NO	Light	Moderate	High			
Other:	YES	NO	Light	Moderate	High			

Appendix Y. Questionnaire pack: the quantitative study

DEAR PARTICIPANT,

Thank you for agreeing to take part in this study.

The study is being conducted at the City, University of London and aims to investigate what helps or prevents people with heart failure in being physically active.

As part of the study, you are being asked to fill in the presented questionnaire. The following questions are about what may influence your physical activity.

The questionnaire takes around 25 minutes and you can complete it in the clinic, by phone or online, whichever you prefer. If you feel uncomfortable answering any questions or are not willing to, please leave them blank. If you decide to not take part in the study, you may withdraw your participation at any point. Please feel free to ask the researcher any questions about the study.

Please contact Aliya Amirova at Aliya.amirova@city.ac.uk if you have any questions about completing this questionnaire pack.

Participant Study Number: | | | | | |

Study group: | | |

Date: | D | D | M | M | M | Y | Y | Y |

Please tell us about yourself

1. **How old are you?**

____

2. **What is your gender?**

☐ Male

☐ Female

☐ Unspecified

3. **What is your level of education?**

☐ No Qualifications

☐ Lower Secondary School (e.g. ‘O’ Level, GCSE)

☐ Higher Secondary School (e.g. ‘AS’ Level, ‘A’ levels)

☐ Further Education (e.g. HND, HNC)

☐ University or Further Degree (e.g. Degree, Master’s, PhD)

4. **What is your relationship status?**

☐ Single

☐ Married/in a relationship

☐ Widowed

☐ Divorced/separated

5. **What is your living status?**

- ☐ Living Alone
- ☐ Living with spouse / partner
- ☐ Living with relatives / friends
- ☐ Living in supported accommodation or equivalent

6. **How would you describe your ethnic background?**

- ☐ English/Welsh/Scottish/Northern Irish/British
- ☐ Gypsy or Irish Traveler
- ☐ Other White Background, please describe:

____

- ☐ British Black
- ☐ Caribbean
- ☐ African
- ☐ Other Black Background, please describe:

____

- ☐ Indian Asian
- ☐ Pakistani Asian
- ☐ Bangladesh
- ☐ Chinese
- ☐ Other Asian Background, please describe:

____

- ☐ Mixed - White and Black Caribbean
- ☐ Mixed - White and Black
- ☐ Mixed - African
- ☐ Mixed - White and Asian
- ☐ Other Mixed Background, please describe

____

- ☐ Arab
- ☐ Any Other Ethnic Background, please describe:

____

Please tell us about your heart failure and the condition of your health

7. **How many years have you had heart failure?**

____

8. **How many times have you been hospitalised in the past year:**

For heart failure?

____

For other reasons?

____

9. **How many medications are you currently taking?**

- ☐ one or two
- ☐ more than two
- ☐ more than five

10. **In general, do you have any health problems that require you to limit your activities?**

- ☐ YES
- ☐ NO

11. **Do you need someone to help you on a regular basis?**

- [ ] YES
- [ ] NO

12. **In general, do you have any health problems that require you to stay at home?**

- [ ] YES
- [ ] NO

---

13. **In case of need can you count on someone close to you?**

- [ ] YES
- [ ] NO

---

14. **Do you regularly use any of the following to get about:**

a stick?

- [ ] YES
- [ ] NO

---

a walker?

- [ ] YES
- [ ] NO

---

a wheelchair?

- ☐ YES
- ☐ NO

My beliefs about physical activity	Strongly agree	Agree	Somewhat agree	Somewhat disagree	Disagree	Strongly disagree
15. I do not know if physical activity is good for me	○	○	○	○	○	○
16. Since I have been diagnosed with heart failure, I am less physically active.	○	○	○	○	○	○
17. The limitations I have in being physically active are just a part of getting older.	○	○	○	○	○	○
18. I have illnesses other than heart failure that make it difficult for me to be physically active.	○	○	○	○	○	○
19. I am not confident in being physically active because of my heart failure.	○	○	○	○	○	○
20. Symptoms of my heart failure (e.g. breathlessness, tight chest, fatigue, swollen legs) limit my ability to be physically active.	○	○	○	○	○	○
21. I keep track of my physical activity to make sure I do not overdo it.	○	○	○	○	○	○

		Strongly agree	Agree	Somewhat agree	Somewhat disagree	Disagree	Strongly disagree
22.	Physical activity improves my general health	○	○	○	○	○	○
23.	Physical activity brings on my heart failure symptoms (e.g. breathlessness; tight chest; swollen legs; extreme fatigue).	○	○	○	○	○	○
24.	I keep track of my physical activity to make sure I do enough.	○	○	○	○	○	○
25.	I fit in enough physical activity in my daily life.	○	○	○	○	○	○
26.	Physical activity helps to improve the strength of my heart.	○	○	○	○	○	○
27.	Not engaging in physical activity makes me feel low	○	○	○	○	○	○
28.	I do not see myself as a physically active person	○	○	○	○	○	○
29.	Being physically active is dangerous because it puts a strain on my heart	○	○	○	○	○	○

30.	Being physically active is a priority for me.						
31.	I keep physically active because it makes me feel more cheerful.						
32.	I try to push myself to do as much physical activity (intensity and /or amount) as I can.						
33.	I do not do much physical activity because a doctor or nurse has advised me to not overdo it.						
34.	I have always been physical active						
35.	Being physically active is something I do without having to think about it.						
36.	I keep on being physically active because it makes me feel better.						
37.	I have a positive outlook on life						

		Strongly agree	Agree	Somewhat agree	Somewhat disagree	Disagree	Strongly disagree
38.	I keep on being physically active to be able to get on with life without help from others.	◯	◯	◯	◯	◯	◯
39.	I already do as much physical activity as I can.	◯	◯	◯	◯	◯	◯
40.	People who are important to me discourage me from being physically active.	◯	◯	◯	◯	◯	◯
41.	I am more likely to do physical activity when I am with other people.	◯	◯	◯	◯	◯	◯
42.	I am physically active because a doctor or a nurse advised me to be.	◯	◯	◯	◯	◯	◯
43.	Being physically active is a big part of my life.	◯	◯	◯	◯	◯	◯
44.	I do not need any training to be able to perform physical activity.	◯	◯	◯	◯	◯	◯
45.	I am a positive person by nature	◯	◯	◯	◯	◯	◯

		Strongly agree	Agree	Somewhat agree	Somewhat disagree	Disagree	Strongly disagree
46.	I am optimistic that physical activity will be good for me.	○	○	○	○	○	○
47.	I will try and engage in some strenuous physical activity in the next week	○	○	○	○	○	○
48.	I am optimistic that I will be physically active in the near future.	○	○	○	○	○	○
49.	Hills, crowds, traffic, or polluted air (i.e. the environment) make it difficult for me to be physically active.	○	○	○	○	○	○
50.	I try to engage in some form of physical activity every week.	○	○	○	○	○	○
51.	I have learnt what physical activity is appropriate for me to do given my diagnosis of heart failure.	○	○	○	○	○	○

52. I am optimistic about my ability to be physically active.	○	○	○	○	○	○
53. Being shown how to do a form of physical activity helped me to become more physically active.	○	○	○	○	○	○
54. I have been shown what physical activity to do since I was diagnosed with heart failure.	○	○	○	○	○	○

	Strongly agree	*Agree*	*Somewhat agree*	*Somewhat disagree*	*Disagree*	*Strongly disagree*

55.	Doing physical activity needs a lot of thought and planning.	○	○	○	○	○	○
56.	I often forget to follow my physical activity routine.	○	○	○	○	○	○
57.	I enjoy engaging in physical activity.	○	○	○	○	○	○
58.	I engage in physical activity because my doctor or nurse are pleased with me when I do.	○	○	○	○	○	○
59.	I have to be in the right mood to engage in physical activity.	○	○	○	○	○	○
60.	I engage in physical activity because people close to me are pleased with me when I do.	○	○	○	○	○	○
61.	Since being diagnosed with heart failure I do more physical activity.	○	○	○	○	○	○
62.	When I think about doing physical activity, I start to worry.	○	○	○	○	○	○

63.	I know how much physical activity I can safely do.	○	○	○	○	○	○
64.	My heart failure treatment prevents me from being physically active.	○	○	○	○	○	○

		Strongly agree	*Agree*	*Somewhat agree*	*Somewhat disagree*	*Disagree*	*Strongly disagree*
65.	Facilities to do physical activity (e.g. a group programme, treadmill, pool) are available to me.	○	○	○	○	○	○
66.	I know how much physical activity I should be doing.	○	○	○	○	○	○
67.	My heart failure treatment (e.g. medication) helps me to be physically active.	○	○	○	○	○	○
68.	Having facilities (e.g. a group programme, treadmill, pool) available to me helps / would help me engage in physical activity.	○	○	○	○	○	○

69. **Have you had a major life event recently (e.g. retirement, death in family, moving house, hospitalisation, surgery, heart attack)?**

○ YES

○ NO: (***if NO, then please skip this page***)

	Strongly agree	*Agree*	*Somewhat agree*	*Somewhat disagree*	*Disagree*	*Strongly disagree*

a)	I do less physical activity than I used to, because of a recent major life-related event. (E.g. retirement, death in family, moving house).	○	○	○	○	○	○
b)	I do more physical activity than I used to, because of a recent major life-related event. (e.g. retirement, death in family, moving house)	○	○	○	○	○	○
c)	I do more physical activity than I used to, because of a recent major health-related event. (e.g. hospitalisation, surgery, heart attack)	○	○	○	○	○	○
d)	I do less physical activity than I used to, because of a recent major health-related event. event (e.g. hospitalisation, surgery, heart attack)	○	○	○	○	○	○

70. Do you have an implantable device?

○ YES

○ NO ***(if No please skip this page)***

	Strongly agree	*Agree*	*Somewhat agree*	*Somewhat disagree*	*Disagree*	*Strongly disagree*

a)	Knowing that I have an implantable device reassures me when I am physically active.	○	○	○	○	○	○
b)	My implantable device could harm me if I am physically active.	○	○	○	○	○	○
c)	My implantable device stops me from being physically active.	○	○	○	○	○	○

Physical Activity Goals and Planning		Strongly agree	Agree	Somewhat agree	Somewhat disagree	Disagree	Strongly disagree
71.	I mentally keep track of my physical activity						
72.	I mentally note specific things that helped me be active						
73.	I set short-term goals for how often I am active						
74.	I set physical activity goals that focus on my health						
75.	I ask someone for physical activity advice or demo						
76.	I ask a physical activity expert or health professional for physical activity advice or demo						
72.	After physical activity I focus on how good it felt						
73.	I remind myself of physical activity health benefits						
74.	I mentally schedule specific times for physical activity						
75.	I rearrange my schedule to ensure I have time for physical activity						

76. I purposely plan ways to do physical activity when on trips away from home						
77. I purposely plan ways to do physical activity in bad weather						

Environment and Safety	Strongly agree	Agree	Somewhat agree	Somewhat disagree	Disagree	Strongly disagree
78. Walking is unsafe because of the traffic						
79. Cycling is unsafe because of the traffic						
80. There are no convenient routes for walking and cycling						
81. There are not enough safe places to cross roads						
82. The area is unsafe because of the level of crime or anti-social behaviour						
83. The area is generally free from litter or graffiti						
84. There are places to walk or cycle to, for example: shops, restaurants, leisure facilities						
85. There are open spaces, for example: parks, sports fields or beaches						
86. There are pavements suitable for walking						

87.	There are special lanes, routes or paths for cycling						
88.	There are many road junctions						
89.	There are many different routes for walking and cycling so I don't have to go the same way every time						
90.	The area is pleasant for walking or cycling						

Social Support from family and friends

Please rate each question twice. Under family, rate how often anyone living in your household has said or done what is described during the last three months. Under friends, rate how often your friends, acquaintances, or coworkers say or do what is said in the items.

Please write one number from the following rating scale in each red square below:

Very often - 1	**Often - 2**	**A few times - 3**	**Rarely - 4**	**None - 5**	**Does not apply - 6**

During the past three months, my family (or members of my household) or friends:

	Family	Friends
91. Exercise with me.		
92. Offer to exercise with me.		

93. Give me helpful reminders to exercise ("Are you going to exercise tonight?”)		
94. Give me encouragement to stick with my exercise program.		
95. Change their schedule so we could exercise together.		
96. Discuss exercise with me.		
97. Complain about the time I spend exercising.		
98. Criticise me or made fun of me for exercising.		
99. Give me rewards for exercising (bought or gave me something I like).		
100. Plan for exercise on recreational outings.		
101. Help plan activities around my exercise.		
102. Ask me for ideas on how they can get more exercise.		
103. Talk about how much they like to exercise.		

	I know I can		Maybe I can		I know I cannot	Does not apply
104. Get up early, even on weekends, to exercise.						
111. Stick to your exercise program after a long, tiring day at work.						
105. Exercise even though you are feeling depressed.						
106. Set aside time for a physical activity program; that is, walking, jogging. Swimming, biking, or other continuous activities for at least 30 minutes, 3 times per week.						
107. Continue to exercise with others even though they seem too fast or too slow for you.						
108. Stick to your exercise program when undergoing a stressful life change (e.g., divorce, death in the family, moving).						
109. Attend a party only after exercising.						
110. Stick to your exercise program when your family is demanding more time from you.						

111. Stick to your exercise program when you have household chores to attend to. 112. Stick to your exercise program even when you have excessive demands at work.						

My confidence in being physically active Below is a list of things people might do while trying to increase or continue regular exercise. We are interested in exercises like running, swimming, brisk walking, bicycle riding, or aerobics classes. Whether you exercise or not, please rate how confident you are that you could really motivate yourself to do things like these consistently, for at least six months. Please circle one number for each question. How sure are you that you can do these things?

Please be as honest and accurate as you can throughout.
Try not to let your response to one statement influence your responses to other statements.
There are no "correct" or "incorrect" answers.
Answer according to your own feelings, rather than how you think "most people" would answer.

	I agree a lot	I agree a little	I neither agree nor disagree	I disagree a little	I disagree a lot
113. In uncertain times, I usually expect the best.					
114. It's easy for me to relax.					
115. If something can go wrong for me, it will.					
116. I'm always optimistic about my future.					
117. I enjoy my friends a lot.					
118. It's important for me to keep busy.					
119. I hardly ever expect things to go my way.					
120. I don't get upset too easily.					
121. I rarely count on good things happening to me.					
122. Overall, I expect more good things to happen to me than bad.					

My breathing

Please read each item and then tick in the box that best matches your breathing these days.
If you do not experience an item tick the “none” box. Please respond to all items.

	None	*Mild*	*Moderate*	*Severe*
123. My breath does not go in all the way				
124. My breathing requires more work				
125. I feel short of breath				
126. I have difficulty catching my breath				
127. I cannot get enough air				
128. My breathing is uncomfortable				
129. My breathing is exhausting				
130. My breathing makes me feel depressed				
131. My breathing makes me feel miserable				
132. My breathing is distressing				
133. My breathing makes me agitated				
134. My breathing is irritating				

	Symptom Frequency				Symptom Severity				This symptom is related to my heart failure
	Almost never	Occasionally	Frequently	Almost all the time	Not applicable	Mildly noticeable	More bothersome	Severe/ Debilitating	

Swollen Ankles									Y N
Chest Pain									Y N
Nausea									Y N
Breathlessness									Y N
Weight Loss									Y N
Weight Gain									Y N
Fatigue									Y N
Stiff Joints									Y N
Shortness of Breath									Y N
Wheeziness									Y N

Headaches									Y N
Tightness in the Chest									Y N
Sleep Difficulties									Y N
Dizziness									Y N
Difficulty Concentrating									Y N
Low Mood									Y N
Loss of Strength									Y N
Other. Specify:									Y N

Appendix Z. Content validity of The Barriers and Enablers to Physical Activity in HF (BEPA-HF) questionnaire.

Five steps are prescribed for assuring that scales are psychometrically sound. This includes: development, presentation, refinement, piloting, and psychometric analysis (DeVellis, 2016). This study follows the three initial steps. A number of frameworks describing psychometric properties exist (e.g. (DeVellis, n.d.); (Anastasi & Urbina, 1997; Messick, 1993). The definitions of psychometric properties are often overlapping across literature (Prinsen et al., 2018). The development of BEPA-HF scale follows Consensus-based Standards for selection of health Measurement Instruments (Terwee et al., 2018) guidelines and its definition of psychometric properties. According to COSMIN, high quality measure requires undergoing an iterative process through which two measurement characteristics - generalisability and interpretability are optimised. The degree to which a measure is interpretable and generalisable is reflected in three measurement properties: validity, reliability and responsiveness. Validity contains the measurement properties such as content validity (including face validity), construct validity (including structural validity, hypotheses testing, and cross-cultural validity\measurement invariance), and criterion validity. Reliability is the degree to which a scale is free of a measurement error. Three properties constitute reliability domain: 1) measurement error 2) reliability 3) and internal consistency. Responsiveness – the third property of a scale – describes the sensitivity of the measurement to the change in the response to the measurement over time. However, before assessing psychometric properties of the scale, foremost it is necessary to confirm that the items of BEPA are relevant, comprehensive, and comprehensible with respect to the construct of interest and target population (Prinsen et al., 2018). This is included in the content validity assessment. Content validity is the degree to which the content of a measurement is an adequate reflection of the construct to be measured (Terwee et al., 2018). Firstly, the content validity of BEPA-HF is ensured in this feasibility study.

1.4.1.1.6.3 Relevance

Elicitation of the relevant constructs was performed using semi-structured interview study. Sixteen qualitative semi-structured interviews about what helps and hinders engaging in physical activity were coded into belief statements. These belief statements served as the content for Barriers and Enablers to Physical Activity in HF (BEPA-HF). The items of BEPA-HF are based on the descriptors of barriers and enablers provided by the participants of the semi-structured interview study. This facilitated the content validity of BEPA-HF as well as its relevance to HF population (Padgett, 1998).

1.4.1.1.6.4 Refinement

Belief statements about the barriers and enablers across the 14 domains formed the content of BEPA-HF, where any item represents a particular identified belief statement. A number of beliefs were dropped to shorten the scale by the panel of experts (SN, KM, SH; please see table 26.1 below). Some belief statements were represented by a number of items to reflect both directions of association between physical activity and the underlying construct, despite evidence (interview responses) supporting either only a negative or positive valence of the relationship between barriers and enablers and physical activity levels. For example, a belief: ‘My physical activity has increased since a major life event (e.g. retirement)’ was expressed by three participants, however, an item ‘my physical activity has decreased since a major life event (e.g. retirement) has been added to the BEPA-HF questionnaire). The scale underwent an iterative review by an expert panel (KM, SH, SN).

1.4.1.1.6.5 Comprehensiveness

The Theoretical Domains Framework was used in informing the interview schedule to ensure broad account of barriers and enablers of physical activity in HF. The detailed discussion of the comprehensiveness enhanced by the implementation of a TDF-based interview topic guide is provided in the chapter outlining the Conceptual Framework of the thesis (Chapter 2).

1.4.1.1.6.6 Readability

The readability of the items has been improved to further develop the content validity of the scale. The Fletch formula provides a commonly used metric of readability, which determines the age and level of education required to comprehend items and is a widely recommended method in literature (Edwards, 2010). The Flesch-Kincaid readability test was applied to all items of the BEPA-HF to assess comprehension difficulty in Microsoft Word. The readability index (Flesch-Kincaid index) was calculated using the following formula: 0.39 (total words/total sentences) + 11.8 (total syllables/total words) – 15.59. If the score dropped below 50, the item was rephrased to improve the score until the score of the scale reached Flesch-Kincaid index equal to or above 60, which corresponds to 7th Grade (United States) and considered as ‘Plain English. Easily understood by 13- to 15-year-old students. Rephrasing entailed using more common words provided as synonyms in English dictionary (REF: website), using shorter words and shorter sentences. It is important to note that the phrase ‘physical activity’ and ‘HF’ considerably reduced the Flesch-Kincaid index and were not included in the assessment of readability (replaced with illness and exercise). This was deemed appropriate because participants are aware what HF means and the term physical activity is explained within the questionnaire pack and information sheet. It is also crucial to the study aims to use generic term ‘physical activity’ rather than exercise (please see Chapter 1).

Appendix Z. Barriers and Enablers of Physical activity in HF (BEPA-HF): Scale Items

Qualitative semi-structured interview findings					**BEPA item**
Theoretical Domains Framework and constituting belief statements	**Construct**	**Barrier/Enabler**	**Number of participants**	**Number of quotes**	
Behavioural Regulation Domain			14	50	
I have a physical activity routine I follow	Habit[1]	Enabler	3	9	Dropped by expert panel
I know when and where I will engage in physical activity over the next week	Planning[1]	Enabler	3	4	Dropped by expert panel
I monitor intensity and or duration of physical activity to make sure I do enough	Self-monitoring[1] (attainment)*	Enabler	3	4	I keep track of my physical activity to make sure I do enough
I monitor the intensity and or duration of physical activity to make sure I do not overdo it	Self-monitoring[1] (fear, downregulation) *	Barrier	2	6	I keep track of my physical activity to make sure I do not overdo it
I pace my physical activity to match my physical ability	Implementation intention[1]	Enabler	10	30	Dropped by expert panel
When weather is bad, I engage in physical activity indoors	Implementation Intention[1]	Enabler	3	4	Dropped by expert panel

Beliefs about Capabilities Domain			16	64	
I lack confidence in engaging in physical activity because of my heart condition	Self-efficacy[1] (Heart Condition)	Barrier	5	8	I am not confident in being physically active because of my heart failure
Illnesses other than HF limit my ability to engage in physical activity	Self-efficacy[1] (Comorbid Chronic Conditions)	Barrier	12	25	I have illnesses other than HF that make it difficult for me to be physically active
My limitations to engaging in physical activity is part of getting older	Self-efficacy[1] (Aging)	Barrier	11	23	The limitation I have in being physically active are just a part of getting older
Symptoms of my HF (e.g. breathlessness; tight chest; fatigue; swollen legs) limit my ability to engage in physical activity	Self-efficacy[1] (HF Symptoms)	Barrier	5	17	Symptoms of my HF (e.g. breathlessness; tight chest; fatigue; swollen legs) limit my ability to be physically active
Beliefs about Consequences Domain			*15*	*83*	
Physical activity improves my general health	Positive outcome expectancy[1]	Enabler	13	36	Physical activity improves my general health
Physical activity brings on my symptoms (e. g. breathlessness)	Negative outcome expectancy[1]	Barrier	10	29	Physical activity brings on my heart failure symptoms (e.g. breathlessness; tight chest; fatigue; swollen legs)

Physical activity makes me breathless	Negative outcome expectancy[1]	Barrier	8	21	The expert panel decided to merge symptom-related beliefs into one item
I engage in physical activity because it makes me feel more cheerful	Positive outcome expectancy[1]	Enabler	6	12	1. I engage in physical activity because it makes me feel more cheerful 2. Not engaging in physical activity makes me feel low
Physical activity Is dangerous because it puts my heart under strain	Risk perception[1]	Barrier	4	6	Being physically active is dangerous because it puts a strain on my heart
Physical activity improves the condition of my heart	Positive outcome expectancy[1]	Enabler	3	4	Physical activity helps to improve the strength of my heart
Physical activities bring on my symptoms (e.g. breathlessness; tight chest; swollen legs; extreme fatigue)	Negative outcome expectancy[1]	Barrier	2	2	Physical activity brings on my heart failure symptoms (e.g. breathlessness; tight chest; swollen legs; extreme fatigue)
Environmental Context and Resources					
My local environment limits me in engaging in physical activity (incline (hills); crowds; traffic; pollution)	Local environment[1]	Barrier	8	20	Hills, crowds, traffic, or polluted air (i.e. the environment) make it difficult for me to be physically active
My HF treatment (e.g. medication) helps me in engaging in physical activity	HF treatment[4]	Enabler	7	18	My HF treatment prevents me from being physically active

Equipment (bike; treadmill) helps me in being active	Equipment[4]	Enabler	5	16	Facilities to do physical activity (e.g. a group programme, treadmill, pool) are available to me
My HF treatment prevents (medication) me from engaging in physical activity	HF treatment[4]	Barrier	7	16	My HF treatment prevents me from being physically active
My physical activity levels decreased since health-related event	Health-related event[2] (barrier)	Barrier	7	11	I do less physical activity than I used to, because of a recent major health- related event. (e.g. hospitalisation, surgery, heart attack)
Having an implantable device reassures me when engaging in physical activity	Implantable device[4] (enabler)	Enabler	4	9	Knowing that I have an implantable device reassures me when I am physically active.
Group programmes help me in being physically active	Exercise-based group programmes[4]	Enabler	5	8	Merged with another item
Facilities (e.g. local council) help me in being physically active	Facilities[4]	Enabler	4	5	Merged with another item
My implantable device can harm me if I engage in physical activity	Implantable device[4] (barrier)	Barrier	2	4	My implantable device could harm me if I am physically active.

					My implantable device stops me from being physically active.
My physical activity levels increased since health-related event	Health-related event[2](enabler)	Enabler	2	4	I do more physical activity than I used to, because of a recent major health- related event. (e.g. hospitalisation, surgery, heart attack)
Decreased since a major life event	Major life events[2] (barrier)	Barrier	3	3	I do less physical activity than I used to, because of a recent major life- related event. (E.g. retirement, death in family, moving house).
Increased since major life event	Major life event[2] (enabler)	Enabler	1	2	I do more physical activity than I used to, because of a recent major life- related event. (e.g. retirement, death in family, moving house)
Goal Domain			15	74	
Engaging in physical activity is a priority for me	Goal priority[2]	Enabler	14	30	Being physically active is a priority for me
I engage in physical activity to be able to get on with life without help from others	Outcome goal[2] (extrinsic motivation[1]	Enabler	9	23	I keep on being physically active to be able to get on with life without help from others

	: functional independence)				
Physical activity is important to me	Goal priority[2]	Enabler	11	22	Dropped by expert panel
I have integrated an adequate amount of physical activity into my life	Behavioural goal[2]: Goal attainment*	Enabler	7	18	I fit in enough physical activity in my daily life
Engaging in physical activity is (not) a priority for me	Goal priority[2]	Barrier	5	8	Dropped by expert panel
I already engage in as much physical activity as I am able to	Behavioural goal[2]: capability-corresponding goal* (lack of intrinsic motivation[1])	Barrier	2	8	I try to push myself to do as much physical activity as I can I already do as much physical activity as I can
Intention Domain			8	14	
I try to engage in some form of physical activity every week	Intention (stability)[2]	Enabler	5	6	I try to engage in some form of physical activity every week
I try and engage in some strenuous physical activity every week	Intention[2]	Enabler	5	8	I will try and engage in some strenuous physical activity in the next week

I do not intend to be active for the sake of being active	Intention (lack)[2]	Barrier	5	8	Merged with another item (Intention-lack of intention is a continuum)
I require training to be able to perform physical activity	Learnt skill[1] (physical)	Barrier	5	6	I do not need any training to be able to perform physical activity Being shown how to do a form physical activity helped me to become more physically active
Social Influences Domain			_11_	_65_	
I engage in physical activity because a health professional (e.g. GP, consultant, nurse, physiotherapist) has advised me to do so	Clinical advice[4] (enabler)	Enabler	7	26	I am physically active because a doctor or a nurse advised me to be
I would engage in physical activity if it involved being with others	Companion ship*	Enabler	5	12	I am more likely to do physical activity when I am with other people
having a reassurance from a health professional that PA is safe encourage me to exercise	Reassuranc e*	Enabler	3	9	Dropped by expert panel
I rely on other people to perform physical activity	Social support[3] (practical)	Barrier	4	6	Dropped by expert panel
I limit my physical activity because a health professional (e.g. GP, nurse, physiotherapist) has advised me to not overdo it	Clinical advice[4] (barrier)	Barrier	2	5	I do not do much physical activity because a doctor or a nurse has advised me to not overdo it

People who are important to me encourage me to be physically active	Social support[3] (emotional, enabler)	Enabler	7	15	People who are important to me encourage me to be physically active
People who are important to me discourage me from engaging in physical activity	Social support[3] (emotional, barrier)	Barrier	5	11	People who are important to me discourage me from being physically active
making plans with others encourage me to engage in physical activity	Social support (practical)[3] linked to behavioural regulation	Enabler	4	7	Dropped by expert panel
I would exercise with others if their level matched my capability	Social comparison [1](linked to self-efficacy)	Barrier	2	4	Dropped by expert panel
Other people are role models	Social modeling[1]	Enabler	3	4	Dropped by expert panel

Note 1. The definition and the construct term is adapted from APA dictionary; 2. The definition and the construct term is adapted from the TDF framework (Davies et al., 2012); 3.The definition and the term is adapted from BCTTv1; 4.The definition and the term is adapted from NICE guidelines; *The construct definition and term is not widely used and not empirically supported. The preliminary names are noted to preserve the specificity of the belief statement content.

9 References

Aalto, A.-M., Heijmans, M., Weinman, J., & Aro, A. R. (2005). Illness perceptions in coronary heart disease. Sociodemographic, illness-related, and psychosocial correlates. Journal of Psychosomatic Research, 58(5), 393–402. https://doi.org/10.1016/j.jpsychores.2005.03.001

Abraham, C. and Michie, S. 2008. A taxonomy of behavior change techniques used in interventions. Health Psychology 27(3), pp. 379–387.

Abraham, C., & Sheeran, P. (2003). Implications of goal theories for the theories of reasoned action and planned behaviour. Current Psychology (New Brunswick, N.J.), 22(3), 264–280. https://doi.org/10.1007/s12144-003-1021-7

Åhlund, K., Bäck, M., & Sernert, N. (2013). Fear-avoidance beliefs and cardiac rehabilitation in patients with first-time myocardial infarction. Journal of Rehabilitation Medicine, 45(10), 1028–1033. https://doi.org/10.2340/16501977-1219

Ainsworth, B. E., Haskell, W. L., Herrmann, S. D., Meckes, N., Bassett, D. R., Tudor-Locke, C., … Leon, A. S. (2011). 2011 Compendium of Physical Activities: a second update of codes and MET values. Medicine and Science in Sports and Exercise, 43(8), 1575–1581. https://doi.org/10.1249/MSS.0b013e31821ece12

Ajiboye, O. A., Anigbogu, C. N., Ajuluchukwu, J. N., & Jaja, S. I. (2015). Exercise training improves functional walking capacity and activity level of Nigerians with chronic biventricular heart failure. Hong Kong Physiotherapy Journal, 33(1), 42–49. https://doi.org/10.1016/j.hkpj.2014.11.002

Al-Hammouri, M. M., Rababah, J. A., & Aldalaykeh, M. (2020). Exploring the potential of acceptance and commitment therapy model in self-care behaviour in persons with heart failure. Nursing Open, 7(5), 1560–1567. https://doi.org/10.1002/nop2.538

Albert, Isabelle, Sophie Donnet, Chantal Guihenneuc-Jouyaux, Samantha Low-Choy, Kerrie Mengersen, and Judith Rousseau. "Combining expert opinions in prior elicitation." Bayesian Analysis 7, no. 3 (2012): 503-532.

Alosco, M.L., Spitznagel, M.B., Miller, L., et al. 2012. Depression is associated with reduced physical activity in persons with heart failure. Health Psychology 31(6), pp. 754–762.

American Psychological Association. (2007). APA Dictionary of Psychology. (American Psychological Association, Ed.) (Vol. 7). Washington, DC: American Psychological Association.

Amirova, A., Fteropoulli, T., Williams, P., & Haddad, M. (2021). Efficacy of interventions to increase physical activity for people with heart failure: a meta-analysis. Open Heart. 8 (1). http://dx.doi.org/10.1136/openhrt-2021-001687

Anastasi, A., & Urbina, S. (1997). Psychological testing. Prentice Hall/Pearson Education.

Anderson, L., & Taylor, R. S. (2014). Cardiac rehabilitation for people with heart disease: an overview of Cochrane systematic reviews. Cochrane Database of Systematic Reviews, (12), CD011273. https://doi.org/10.1002/14651858.CD011273.pub2

Anderson, L., Sharp, G. A., Norton, R. J., Dalal, H., Dean, S. G., Jolly, K., … Taylor, R. S. (2017). Home-based versus centre-based cardiac rehabilitation. Cochrane Database of Systematic Reviews, 6, CD007130. https://doi.org/10.1002/14651858.CD007130.pub4

Andreae, C., Årestedt, K., Evangelista, L. and Strömberg, A. 2019. The relationship between physical activity and appetite in patients with heart failure: A prospective observational study. European journal of cardiovascular nursing : journal of the Working Group on Cardiovascular Nursing of the European Society of Cardiology 18(5), pp. 410–417.

Anker, S.D., Koehler, F. and Abraham, W.T. 2011. Telemedicine and remote management of patients with heart failure. The Lancet 378(9792), pp. 731–739.

Araújo-Soares, V., Hankonen, N., Presseau, J., Rodrigues, A., & Sniehotta, F. F. (2019). Developing Behavior Change Interventions for Self-Management in Chronic Illness: An Integrative Overview. European Psychologist, 24(1), 7–25. https://doi.org/10.1027/1016-9040/a000330

Atkins, L., Francis, J., Islam, R., et al. 2017. A guide to using the Theoretical Domains Framework of behaviour change to investigate implementation problems. Implementation Science 12(1), p. 77.

Aujla, N., Walker, M., Sprigg, N., Abrams, K., Massey, A., & Vedhara, K. (2016). Can illness beliefs, from the common-sense model, prospectively predict adherence to self-management behaviours? A systematic review and meta-analysis. Psychology & Health, 31(8), 931–958. https://doi.org/10.1080/08870446.2016.1153640

Bailey, K. R. I. (1987). Inter-study differences: How should they influence the interpretation and analysis of results? Statistics in medicine (6), 351–358.

Bandura, A. (1997). Self-efficacy: The exercise of control: Macmillan.

Bandura, A. (2002). Social foundations of thought and action. In The health psychology reader (pp. 94–106). 1 Oliver's Yard, 55 City Road, London EC1Y 1SP United Kingdom : SAGE Publications Ltd. https://doi.org/10.4135/9781446221129.n6

Bandura, A. (2006). Toward a psychology of human agency. Perspectives on Psychological Science : A Journal of the Association for Psychological Science, 1(2), 164–180. https://doi.org/10.1111/j.1745-6916.2006.00011.x

Barbour, K. A., & Miller, N. H. (2008). Adherence to exercise training in heart failure: a review. Heart Failure Reviews, 13(1), 81–89. https://doi.org/10.1007/s10741-007-9054-x

Barnason, S., Zimmerman, L., Nieveen, J., Schmaderer, M., Carranza, B., & Reilly, S. (2003). Impact of a home communication intervention for coronary artery bypass graft patients with ischemic heart failure on self-efficacy, coronary disease risk factor modification, and functioning. Heart & Lung : The Journal of Critical Care, 32(3), 147–158.

Barr, I. (2018). causalgraphicalmodels 0.0.4 on PyPI - Libraries.io. Retrieved September 25, 2020, from https://libraries.io/pypi/causalgraphicalmodels

Beard, E., & West, R. (2017). Using Bayesian statistics in health psychology: a comment on Depaoli et al. (2017). Health Psychology Review, 11(3), 298–301. https://doi.org/10.1080/17437199.2017.1349544

Bearne, L., Galea Holmes, M., Bieles, J., Eddy, S., Fisher, G., Modarai, B., … Weinman, J. (2019). Motivating Structured walking Activity in people with Intermittent Claudication (MOSAIC): protocol for a randomised controlled trial of a physiotherapist-led, behavioural change intervention versus usual care in adults with intermittent claudication. BMJ Open, 9(8), e030002. https://doi.org/10.1136/bmjopen-2019-030002

Begg, C. B. (1994). Publication bias. The Handbook of Research Synthesis, 25, 299–409.

Belardinelli, R., Georgiou, D., Cianci, G., & Purcaro, A. (2012). 10-year exercise training in chronic heart failure: a randomized controlled trial. Journal of the American College of Cardiology, 60(16), 1521–1528. https://doi.org/10.1016/j.jacc.2012.06.036

Bellg, A. J., Borrelli, B., Resnick, B., Hecht, J., Minicucci, D. S., Ory, M., … Treatment Fidelity Workgroup of the NIH Behavior Change Consortium. (2004). Enhancing treatment fidelity in health behavior change studies: best practices and recommendations from the NIH Behavior Change Consortium. Health Psychology, 23(5), 443–451. https://doi.org/10.1037/0278-6133.23.5.443

Berg-Emons, R., Balk, A., Bussmann, H., & Stam, H. (2004). Does aerobic training lead to a more active lifestyle and improved quality of life in patients with chronic HF? European journal of HF, 6(1), 95-100.

Berkman, N. D., Sheridan, S. L., Donahue, K. E., Halpern, D. J., Viera, A., Crotty, K., ... & Tant, E. (2011). Health literacy interventions and outcomes: an updated systematic review. Evid Rep Technol Assess (Full Rep), 199(1), 941.

Bernocchi, P., Vitacca, M., La Rovere, M. T., Volterrani, M., Galli, T., Baratti, D., … Scalvini, S. (2018). Home-based telerehabilitation in older patients with chronic obstructive pulmonary disease and heart failure: a randomised controlled trial. Age and Ageing, 47(1), 82–88. https://doi.org/10.1093/ageing/afx146

Berry, C., Murdoch, D. R., & McMurray, J. J. (2001). Economics of chronic heart failure. European Journal of Heart Failure, 3(3), 283–291. https://doi.org/10.1016/s1388-9842(01)00123-4

Beswick, A. D., Rees, K., Griebsch, I., Taylor, F. C., Burke, M., West, R. R., … Ebrahim, S. (2004). Provision, uptake and cost of cardiac rehabilitation programmes: improving services to under-represented groups. Health Technology Assessment, 8(41), iii–iv, ix. https://doi.org/10.3310/hta8410

Bjarnason-Wehrens, B., McGee, H., Zwisler, A.-D., Piepoli, M. F., Benzer, W., Schmid, J.-P., . . . Niebauer, J. (2010). Cardiac rehabilitation in Europe: Results from the European cardiac rehabilitation inventory survey. European Journal of Cardiovascular Prevention & Rehabilitation, 17(4), 410-418.

Bogosian, A. (2012). Psychosocial adjustment in adolescents with a parent with multiple sclerosis (Undergraduate thesis).

Bogosian, Angeliki, Moss-Morris, R., Bishop, F. L., & Hadwin, J. (2014). Development and initial validation of the Perceptions of Parental Illness Questionnaire. Journal of Health Psychology, 19(7), 931–942. https://doi.org/10.1177/1359105313482164

Bollen, K. A. (1990). Overall fit in covariance structure models: Two types of sample size effects. Psychological bulletin, 107(2), 256.

Borenstein, M., Hedges, L. V., Higgins, J. P. T., & Rothstein, H. R. (2009). Introduction to Meta-Analysis. Chichester, UK: John Wiley & Sons, Ltd. https://doi.org/10.1002/9780470743386

Borenstein, M., Hedges, L., Higgins, J., & Rothstein, H. (2005). Comprehensive meta-analysis version 2. Englewood, NJ: Biostat, 104.

Borland, R. (2017). CEOS theory: A comprehensive approach to understanding hard to maintain behaviour change. Applied Psychology. Health and Well-Being, 9(1), 3–35. https://doi.org/10.1111/aphw.12083

Boyne, J. J. J., Vrijhoef, H. J. M., Spreeuwenberg, M., De Weerd, G., Kragten, J., Gorgels, A. P. M., & TEHAF investigators. (2014). Effects of tailored telemonitoring on heart failure patients' knowledge, self-care, self-efficacy and adherence: a randomized controlled trial. European Journal of Cardiovascular Nursing : Journal of the Working Group on Cardiovascular Nursing of the European Society of Cardiology, 13(3), 243–252. https://doi.org/10.1177/1474515113487464

Braun, V. and Clarke, V. 2006. Using thematic analysis in psychology. Qualitative research in psychology 3(2), pp. 77–101.

Brodie, D. A., & Inoue, A. (2005). Motivational interviewing to promote physical activity for people with chronic heart failure. Journal of Advanced Nursing, 50(5), 518–527. https://doi.org/10.1111/j.1365-2648.2005.03422.x

Butrous, H., & Hummel, S. L. (2016). Heart failure in older adults. The Canadian Journal of Cardiology, 32(9), 1140–1147. https://doi.org/10.1016/j.cjca.2016.05.005

Byberg, L., Melhus, H., Gedeborg, R., Sundström, J., Ahlbom, A., Zethelius, B., … Michaëlsson, K. (2009). Total mortality after changes in leisure time physical activity in 50 year old men: 35 year follow-up of population based cohort. BMJ (Clinical Research Ed.), 338, b688. https://doi.org/10.1136/bmj.b688

Campbel, M. (2003). The process of implementing the Stanford Model Chronic Disease Self-management Program: the Northern Hospital experience. Australian Journal of Primary Health, 9(3), 127-131.

Cane, J., O'Connor, D., & Michie, S. (2012). Validation of the theoretical domains framework for use in behaviour change and implementation research. Implementation Science, 7, 37. https://doi.org/10.1186/1748-5908-7-37

Cane, J., Richardson, M., Johnston, M., Ladha, R., & Michie, S. (2015). From lists of behaviour change techniques (BCTs) to structured hierarchies: comparison of two methods of developing a hierarchy of BCTs. British Journal of Health Psychology, 20(1), 130-150.

Caracelli, V. J., & Greene, J. C. (1993). Data analysis strategies for mixed-method evaluation designs. Educational evaluation and policy analysis, 15(2), 195-207.

Carroll, C., Patterson, M., Wood, S., Booth, A., Rick, J., & Balain, S. (2007). A conceptual framework for implementation fidelity. Implementation Science, 2, 40. https://doi.org/10.1186/1748-5908-2-40

Carver, C.S. and Scheier, M.F. 2012. Attention and self-regulation: A control-theory approach to human behavior. Springer Science & Business Media.

CG108. London: NICE, 2010. http://guidance.nice.org.uk/nicemedia/

Chan, A.-W., & Altman, D. G. (2005). Identifying outcome reporting bias in randomised trials on PubMed: review of publications and survey of authors. BMJ: British Medical Journal, 330(7494), 753.

Chen, M.-H., Ibrahim, J. G., & Kim, S. (2008). Properties and implementation of jeffreys's prior in binomial regression models. Journal of the American Statistical Association, 103(484), 1659–1664. https://doi.org/10.1198/016214508000000779

Chien, H. C., Chen, H. M., Garet, M., & Wang, R. H. (2014). Predictors of physical activity in patients with HF: a questionnaire study. Journal of Cardiovascular Nursing, 29(4), 324-331.

Chilcot, J., Norton, S., Wellsted, D., & Farrington, K. (2012). The factor structure of the Revised Illness Perception Questionnaire (IPQ-R) in end-stage renal disease patients. Psychology, Health & Medicine, 17(5), 578–588. https://doi.org/10.1080/13548506.2011.647702

Choy, Samantha Low, Rebecca O'Leary, and Kerrie Mengersen. "Elicitation by design in ecology: using expert opinion to inform priors for Bayesian statistical models." Ecology 90, no. 1 (2009): 265-277.

Clark, A. M., Redfern, J., & Briffa, T. (2014). Cardiac rehabilitation: fit to face the future? Heart, 100(5), 355–356. https://doi.org/10.1136/heartjnl-2013-304407

Clarke, V. and Braun, V. 2014. Thematic Analysis. In: Teo, T. ed. Encyclopedia of critical psychology. New York, NY: Springer New York, pp. 1947–1952.

Collins, E., Langbein, W. E., Dilan-Koetje, J., Bammert, C., Hanson, K., Reda, D., & Edwards, L. (2004). Effects of exercise training on aerobic capacity and quality of life in individuals with heart failure. Heart & Lung : The Journal of Critical Care, 33(3), 154–161. https://doi.org/10.1016/j.hrtlng.2003.12.009

Conner, M., Abraham, C., Prestwich, A., Hutter, R., Hallam, J., Sykes-Muskett, B., … Hurling, R. (2016). Impact of goal priority and goal conflict on the intention-health-behavior relationship: Tests on physical activity and other health behaviors. Health Psychology, 35(9), 1017–1026. https://doi.org/10.1037/hea0000340

Conraads, V. M., Deaton, C., Piotrowicz, E., Santaularia, N., Tierney, S., Piepoli, M. F., … Jaarsma, T. (2012). Adherence of heart failure patients to exercise: barriers and possible solutions: a position statement of the Study Group on Exercise Training in Heart Failure of the Heart Failure Association of the European Society of Cardiology. European Journal of Heart Failure, 14(5), 451–458. https://doi.org/10.1093/eurjhf/hfs048

Cooper, A. F., Weinman, J., Hankins, M., Jackson, G., & Horne, R. (2007). Assessing patients' beliefs about cardiac rehabilitation as a basis for predicting attendance after acute myocardial infarction. Heart, 93(1), 53–58. https://doi.org/10.1136/hrt.2005.081299

Corvera-Tindel, T., Doering, L. V., Woo, M. A., Khan, S., & Dracup, K. (2004a). Effects of a home walking exercise program on functional status and symptoms in HF. American heart journal, 147(2), 339-346.

Corvera-Tindel, T., Doering, L.V., Gomez, T. and Dracup, K. 2004b. Predictors of noncompliance to exercise training in heart failure. The Journal of Cardiovascular Nursing 19(4), p. 269–77; quiz 278.

Cowie, A., Thow, M. K., Granat, M. H., & Mitchell, S. L. (2011). A comparison of home and hospital-based exercise training in heart failure: immediate and long-term effects upon physical activity level. European Journal of Cardiovascular Prevention & Rehabilitation, 18(2), 158–166. https://doi.org/10.1177/1741826710389389

Cradock, K. A., ÓLaighin, G., Finucane, F. M., Gainforth, H. L., Quinlan, L. R., & Ginis, K. A. M. (2017). Behaviour change techniques targeting both diet and physical activity in type 2 diabetes: A systematic review and meta-analysis. International Journal of Behavioral Nutrition and Physical Activity, 14(1), 18.

Craig, P., Dieppe, P., Macintyre, S., Michie, S., Nazareth, I., & Petticrew, M. (2008). Developing and evaluating complex interventions: the new Medical Research Council guidance. BMJ: British Medical Journal, 337, a1655.

Creswell, J. W., & Miller, D. L. (2000). Determining validity in qualitative inquiry. Theory into Practice, 39(3), 124–130. https://doi.org/10.1207/s15430421tip3903_2

Creswell, J. W., & Palno Clark, V. L. P. (2011). Designing and Conducting Mixed Methods Research: SAGE.

Creswell, J. W., & Plano Clark, V. L. P. (2007). Designing and conducting mixed methods research.

Creswell, J.W. and Miller, D.L. 2000. Determining validity in qualitative inquiry. Theory into practice 39(3), pp. 124–130.

Crowley, S. L., & Fan, X. (1997). Structural equation modeling: Basic concepts and applications in personality assessment research. Journal of personality assessment, 68(3), 508-531.

Dalal, H. M., Lang, C. C., Smith, K., Wingham, J., Eyre, V., Greaves, C. J., … On behalf of the REACH-HF Investigators. (2018). A randomised controlled trial of a facilitated home-based rehabilitation intervention in patients with heart failure with preserved ejection fraction and their caregivers: REACH-HFpEF pilot study. The British Journal of General Practice, 68(suppl 1), bjgp18X697013. https://doi.org/10.3399/bjgp18X697013

Dalal, H. M., Zawada, A., Jolly, K., Moxham, T., & Taylor, R. S. (2010). Home based versus centre based cardiac rehabilitation: Cochrane systematic review and meta-analysis. BMJ: British Medical Journal, 340, b5631.

Davies, E. J., Moxham, T., Rees, K., Singh, S., Coats, A. J. S., Ebrahim, S., … Taylor, R. S. (2010). Exercise training for systolic heart failure: Cochrane systematic review and

meta-analysis. European Journal of Heart Failure, 12(7), 706–715. https://doi.org/10.1093/eurjhf/hfq056
Davis, R., Campbell, R., Hildon, Z., Hobbs, L., & Michie, S. (2015). Theories of behaviour and behaviour change across the social and behavioural sciences: a scoping review. Health psychology review, 9(3), 323-344.
Dayan, P. (2009). Goal-directed control and its antipodes. Neural Networks, 22(3), 213–219. https://doi.org/10.1016/j.neunet.2009.03.004
Dayan, P. and Berridge, K.C. 2014. Model-based and model-free Pavlovian reward learning: revaluation, revision, and revelation. Cognitive, Affective & Behavioral Neuroscience 14(2), pp. 473–492.
Dayan, P., Niv, Y., Seymour, B., & Dawa, N. (2006). The misbehavior of value and the discipline of the will. Neural Networks, 19(8)(8), pp.1153-1160.
Debray, T. P. A., Damen, J. A. A. G., Snell, K. I. E., Ensor, J., Hooft, L., Reitsma, J. B., … Moons, K. G. M. (2017). A guide to systematic review and meta-analysis of prediction model performance. BMJ (Clinical Research Ed.), 356, i6460. https://doi.org/10.1136/bmj.i6460
Dekkers, O. M., Vandenbroucke, J. P., Cevallos, M., Renehan, A. G., Altman, D. G., & Egger, M. (2019). COSMOS-E: Guidance on conducting systematic reviews and meta-analyses of observational studies of etiology. PLoS Medicine, 16(2), e1002742. https://doi.org/10.1371/journal.pmed.1002742
Depaoli, S., Rus, H. M., Clifton, J. P., van de Schoot, R., & Tiemensma, J. (2017). An introduction to Bayesian statistics in health psychology. Health Psychology Review, 11(3), 248–264. https://doi.org/10.1080/17437199.2017.1343676
DeVellis, R. F. (2016). Scale development: Theory and applications. books.google.com.
Dibben, G. O., Dalal, H. M., Taylor, R. S., Doherty, P., Tang, L. H., & Hillsdon, M. (2018). Cardiac rehabilitation and physical activity: systematic review and meta-analysis. Heart, 104(17), 1394–1402. https://doi.org/10.1136/heartjnl-2017-312832
Dixon-Woods, M., Agarwal, S., Jones, D., Young, B., & Sutton, A. (2005). Synthesising qualitative and quantitative evidence: a review of possible methods. Journal of Health Services Research & Policy, 10(1), 45–53. https://doi.org/10.1258/1355819052801804
Doan, S., Yang, E. W., Tilak, S. S., Li, P. W., Zisook, D. S., & Torii, M. (2019). Extracting health-related causality from twitter messages using natural language processing. BMC Medical Informatics and Decision Making, 19(Suppl 3), 79. https://doi.org/10.1186/s12911-019-0785-0
Doherty, P. J., & Harrison, A. S. (2017). The National Audit of Cardiac Rehabilitation: Annual Statistical Report 2017.
Dontje, M.L., van der Wal, M.H.L., Stolk, R.P., et al. 2014. Daily physical activity in stable heart failure patients. The Journal of Cardiovascular Nursing 29(3), pp. 218–226.
Duncan, K., & Pozehl, B. (2003). Effects of an exercise adherence intervention on outcomes in patients with heart failure. Rehabilitation Nursing : The Official Journal of the Association of Rehabilitation Nurses, 28(4), 117–122.
Duval, S., & Tweedie, R. (2000). Trim and fill: a simple funnel-plot–based method of testing and adjusting for publication bias in meta-analysis. Biometrics, 56(2), 455-463.
Edwards, P. (2010). Questionnaires in clinical trials: guidelines for optimal design and administration. Trials, 11, 2. https://doi.org/10.1186/1745-6215-11-2
Egger, M., Smith, G. D., Schneider, M., & Minder, C. (1997). Bias in meta-analysis detected by a simple, graphical test. BMJ: British Medical Journal, 315(7109), 629-634.
Eisenhofer, G., Friberg, P., Rundqvist, B., Quyyumi, A. A., Lambert, G., Kaye, D. M., . . . Esler, M. D. (1996). Cardiac sympathetic nerve function in congestive HF. Circulation, 93(9), 1667-1676.

Elixhauser, A., Steiner, C., Harris, D. R., & Coffey, R. M. (1998). Comorbidity measures for use with administrative data. Medical care, 36(1), 8-27.
Elzen, H., Slaets, J. P., Snijders, T. A., & Steverink, N. (2007). Evaluation of the chronic disease self-management program (CDSMP) among chronically ill older people in the Netherlands. Social Science & Medicine, 64(9), 1832-1841.
Esliger, D. W., Copeland, J. L., Barnes, J. D., & Tremblay, M. S. (2005). Standardizing and optimizing the use of accelerometer data for free-living physical activity monitoring. Journal of Physical Activity and Health, 2(3), 366-383.
Evangelista, L., Doering, L. V., Dracup, K., Westlake, C., Hamilton, M., & Fonarow, G. C. (2003). Compliance behaviors of elderly patients with advanced heart failure. The Journal of Cardiovascular Nursing, 18(3), 197–206; quiz 207.
Evangelista, L.S., Berg, J. and Dracup, K. 2001. Relationship between psychosocial variables and compliance in patients with heart failure. Heart & lung : the journal of critical care 30(4), pp. 294–301.
ExTraMATCH Collaborative (2004). Exercise training meta-analysis of trials in patients with chronic HF (ExTraMATCH). BMJ: British Medical Journal, 328(7433), 189.
Ferrier, S., Blanchard, C. M., Vallis, M., & Giacomantonio, N. (2011). Behavioural interventions to increase the physical activity of cardiac patients: a review. European Journal of Cardiovascular Prevention & Rehabilitation, 18(1), 15-32.
Fletcher, G. F., Froelicher, V. F., Hartley, L. H., Haskell, W. L., & Pollock, M. L. (1990). Exercise standards. A statement for health professionals from the American Heart Association. Circulation, 82(6), 2286-2322.
Floyd, R. L., Sobell, M., Velasquez, M. M., Ingersoll, K., Nettleman, M., Sobell, L., . . . Bolton, B. (2007). Preventing alcohol-exposed pregnancies: a randomized controlled trial. American journal of preventive medicine, 32(1), 1-10.
Francis, J. J., Stockton, C., Eccles, M. P., Johnston, M., Cuthbertson, B. H., Grimshaw, J. M., … Stanworth, S. J. (2009). Evidence-based selection of theories for designing behaviour change interventions: using methods based on theoretical construct domains to understand clinicians’ blood transfusion behaviour. British Journal of Health Psychology, 14(Pt 4), 625–646. https://doi.org/10.1348/135910708X397025
Freedland, K. E., Carney, R. M., Rich, M. W., Steinmeyer, B. C., & Rubin, E. H. (2015). Cognitive Behavior Therapy for Depression and Self-Care in Heart Failure Patients: A Randomized Clinical Trial. JAMA Internal Medicine, 175(11), 1773–1782. https://doi.org/10.1001/jamainternmed.2015.5220
French, D. P., Marteau, T. M., Senior, V., & Weinman, J. (2002). The structure of beliefs about the causes of heart attacks: A network analysis. British Journal of Health Psychology, 7(Part 4), 463–479. https://doi.org/10.1348/135910702320645426
French, D. P., Olander, E. K., Chisholm, A., & Mc Sharry, J. (2014). Which behaviour change techniques are most effective at increasing older adults’ self-efficacy and physical activity behaviour? A systematic review. Annals of behavioral medicine, 48(2), 225-234.
Gad, S. A., Martin, S., Kimber, S., Williams, R., Gulamhusein, S., Lockwood, E., & Haennel, R. G. (2018). Impact of cardiac resynchronization therapy on daily physical activity in heart failure patients. Journal of Cardiopulmonary Rehabilitation and Prevention, 38(6), E1–E4. https://doi.org/10.1097/HCR.0000000000000345
Gainforth, H. L., Sheals, K., Atkins, L., Jackson, R., & Michie, S. (2016). Developing interventions to change recycling behaviors: A case study of applying behavioral science. Applied Environmental Education & Communication, 15(4), 325-339.
Gallagher, R., Luttik, M. L., & Jaarsma, T. (2011). Social support and self-care in heart failure. Journal of Cardiovascular Nursing, 26(6), 439-445.

Gardner, B. (2018). Habit formation and behavior change (Vol. 1). Oxford University Press. https://doi.org/10.1093/acrefore/9780190236557.013.129
Garet, M., Degache, F., Pichot, V., et al. 2005. Relationship between daily physical activity and ANS activity in patients with CHF. Medicine and Science in Sports and Exercise 37(8), pp. 1257–1263.
Gebhardt, W. A., & Maes, S. (1998). Competing personal goals and exercise behaviour. Perceptual and Motor Skills, 86(3 Pt 1), 755–759. https://doi.org/10.2466/pms.1998.86.3.755
Gelman, A., Carlin, J. B., Stern, H. S., & Rubin, D. B. (2003). Bayesian Data Analysis, Second Edition (2, revised ed.). CRC Press.
Gholami, M., Knoll, N., & Schwarzer, R. (2014). Application of the health action process approach to physical activity: A meta-analysis. Self-Regulation and Health Behavior Across the Life Span, 72.
Godin, G., & Shephard, R. (1985). A simple method to assess exercise behavior in the community. Can J Appl Sport Sci, 10(3), 141-146.
Godin, G., Bélanger-Gravel, A., Eccles, M., & Grimshaw, J. (2008). Healthcare professionals' intentions and behaviours: a systematic review of studies based on social cognitive theories. Implementation Science, 3, 36. https://doi.org/10.1186/1748-5908-3-36
Gold, S. M., Köhler-Forsberg, O., Moss-Morris, R., Mehnert, A., Miranda, J. J., Bullinger, M., … Otte, C. (2020). Comorbid depression in medical diseases. Nature Reviews. Disease Primers, 6(1), 69. https://doi.org/10.1038/s41572-020-0200-2
Goldstein, C. M., Gathright, E. C., & Garcia, S. (2017). Relationship between depression and medication adherence in cardiovascular disease: the perfect challenge for the integrated care team. Patient Preference and Adherence, 11, 547–559. https://doi.org/10.2147/PPA.S127277
Golin, C. E., Earp, J. A., Grodensky, C. A., Patel, S. N., Suchindran, C., Parikh, M., . . . Quinlivan, E. B. (2012). Longitudinal effects of SafeTalk, a motivational interviewing-based program to improve safer sex practices among people living with HIV/AIDS. AIDS and Behavior, 16(5), 1182-1191.
Gollwitzer, P. M., & Brandstätter, V. (1997). Implementation intentions and effective goal pursuit. Journal of Personality and Social Psychology, 73(1), 186–199. https://doi.org/10.1037/0022-3514.73.1.186
Gollwitzer, P. M., & Sheeran, P. (2006). Implementation intentions and goal achievement: A meta-analysis of effects and processes. In Advances in experimental social psychology volume 38 (Vol. 38, pp. 69–119). Elsevier. https://doi.org/10.1016/S0065-2601(06)38002-1
Gollwitzer, P.M. and Brandstätter, V. 1997. Implementation intentions and effective goal pursuit. Journal of Personality and Social Psychology 73(1), pp. 186–199.
González, B., Lupón, J., Parajón, T., et al. 2004. Nurse evaluation of patients in a new multidisciplinary Heart Failure Unit in Spain. European journal of cardiovascular nursing : journal of the Working Group on Cardiovascular Nursing of the European Society of Cardiology 3(1), pp. 61–69.
Greaves, C. J., Sheppard, K. E., Abraham, C., Hardeman, W., Roden, M., Evans, P. H., & Schwarz, P. (2011). Systematic review of reviews of intervention components associated with increased effectiveness in dietary and physical activity interventions. BMC public health, 11(1), 119.
Greene, S. J., Hernandez, A. F., Dunning, A., Ambrosy, A. P., Armstrong, P. W., Butler, J., . . . Metra, M. (2017). Hospitalization for recently diagnosed versus worsening chronic

HF: from the ASCEND-HF trial. Journal of the American College of Cardiology, 69(25), 3029-3039.
Gu, X., Hoijtink, H., Mulder, J. and Rosseel, Y. 2019. Bain: a program for Bayesian testing of order constrained hypotheses in structural equation models. Journal of statistical computation and simulation 89(8), pp. 1526–1553.https://doi.org/10.1080/00949655.2019.1590574
Guest, O., & Martin, A. E. (2020). How computational modeling can force theory building in psychological science. https://doi.org/10.31234/osf.io/rybh9
Haedtke, C., Smith, M., VanBuren, J., Klein, D. and Turvey, C. 2017. The relationships among pain, depression, and physical activity in patients with heart failure. The Journal of Cardiovascular Nursing 32(5), pp. E21–E25.
Hagger, M. S. (2009). Theoretical integration in health psychology: Unifying ideas and complementary explanations. British Journal of Health Psychology, 14(2), 189-194.
Hagger, M. S., & Orbell, S. (2003). A Meta-Analytic Review of the Common-Sense Model of Illness Representations. Psychology & Health, 18(2), 141–184. https://doi.org/10.1080/088704403100081321
Hagger, M. S., & Orbell, S. (2005). A confirmatory factor analysis of the revised illness perception questionnaire (IPQ-R) in a cervical screening context. Psychology & Health, 20(2), 161–173. https://doi.org/10.1080/0887044042000334724
Hagger, M. S., Cameron, L. D., Hamilton, K., Hankonen, N., & Lintunen, T. (Eds.). (2020). The handbook of behavior change. Cambridge University Press. https://doi.org/10.1017/9781108677318
Hagger, M. S., Koch, S., Chatzisarantis, N. L. D., & Orbell, S. (2017). The common sense model of self-regulation: Meta-analysis and test of a process model. Psychological Bulletin, 143(11), 1117–1154. https://doi.org/10.1037/bul0000118
Hale, J., Hastings, J., West, R., Lefevre, C. E., Direito, A., Bohlen, L. C., … Michie, S. (2020). An ontology-based modelling system (OBMS) for representing behaviour change theories applied to 76 theories. Wellcome Open Research, 5, 177. https://doi.org/10.12688/wellcomeopenres.16121.1
Hamilton, K., Marques, M. M., & Johnson, B. T. (2017). Advanced analytic and statistical methods in health psychology. Health Psychology Review, 11(3), 217–221. https://doi.org/10.1080/17437199.2017.1348905
Hankonen, N., & Hardeman, W. (2020). Developing Complex Behaviour Change Interventions. In M. Hagger, L. Cameron, K. Hamilton, N. Hankonen, & T. Lintunen (Eds.), The Handbook of Behaviour Change.
Hardeman, W., Johnston, M., Johnston, D., Bonetti, D., Wareham, N., & Kinmonth, A. L. (2002). Application of the theory of planned behaviour in behaviour change interventions: A systematic review. Psychology and health, 17(2), 123-158.
Harrison, J. M., Jung, M., Lennie, T. A., Moser, D. K., Smith, D. G., Dunbar, S. B., ... & Pressler, S. J. (2016). Refusal to participate in heart failure studies: do age and gender matter?. Journal of clinical nursing, 25(7-8), 983-991.
Heart: National Heart Failure Audit – HQIP. (n.d.). Retrieved March 1, 2020, from https://www.hqip.org.uk/a-z-of-nca/heart-failure-audit/
Heckman, C. J., Egleston, B. L., & Hofmann, M. T. (2010). Efficacy of motivational interviewing for smoking cessation: a systematic review and meta-analysis. Tobacco control, 19(5), 410-416.
Hein, S., Arnon, E., Kostin, S., Schönburg, M., Elsässer, A., Polyakova, V., . . . Schaper, J. (2003). Progression from compensated hypertrophy to failure in the pressure-overloaded human heart. Circulation, 107(7), 984-991.

Heino, M. T. J., Vuorre, M., & Hankonen, N. (2018). Bayesian evaluation of behavior change interventions: a brief introduction and a practical example. Health Psychology and Behavioral Medicine, 6(1), 49–78. https://doi.org/10.1080/21642850.2018.1428102
Higgins, Altman, D. G., Gøtzsche, P. C., Jüni, P., Moher, D., Oxman, A. D., . . . Sterne, J. A. (2011a). The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. BMJ: British Medical Journal, 343, d5928.
Higgins, J. P. T., Altman, D. G., Gøtzsche, P. C., Jüni, P., Moher, D., Oxman, A. D., . . . Sterne, J. A. C. (2011b). The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. BMJ: British Medical Journal, 343. doi:10.1136/bmj.d5928
Higgins, J. P., & Green, S. (2017). Cochrane Handbook for Systematic Reviews of Interventions, Version 5.1. 0. London: The Cochrane Collaboration; 2011.
Higgins, J., & Thompson, S. G. (2002). Quantifying heterogeneity in a meta-analysis. Statistics in medicine, 21(11), 1539-1558.
Ho, T. H., Caughey, G. E., & Shakib, S. (2014). Guideline compliance in chronic heart failure patients with multiple comorbid diseases: evaluation of an individualised multidisciplinary model of care. Plos One, 9(4), e93129. https://doi.org/10.1371/journal.pone.0093129
Hoffmann, T. C., Glasziou, P. P., Boutron, I., Milne, R., Perera, R., Moher, D., . . . Johnston, M. (2014). Better reporting of interventions: template for intervention description and replication (TIDieR) checklist and guide. BMJ: British Medical Journal, 348, g1687.
Hollands, G. J., Bignardi, G., Johnston, M., Kelly, M. P., Ogilvie, D., Petticrew, M., … Marteau, T. M. (2017). The TIPPME intervention typology for changing environments to change behaviour. Nature Human Behaviour, 1(8), 0140. https://doi.org/10.1038/s41562-017-0140
Hollands, G. J., Shemilt, I., Marteau, T. M., Jebb, S. A., Kelly, M. P., Nakamura, R., … Ogilvie, D. (2013). Altering micro-environments to change population health behaviour: towards an evidence base for choice architecture interventions. BMC Public Health, 13, 1218. https://doi.org/10.1186/1471-2458-13-1218
Hollands, G.J., Bignardi, G., Johnston, M., et al. 2017. The TIPPME intervention typology for changing environments to change behaviour. Nature Human Behaviour 1(8), p. 0140.
Hollands, G.J., Shemilt, I., Marteau, T.M., et al. 2013. Altering micro-environments to change population health behaviour: towards an evidence base for choice architecture interventions. BMC Public Health 13, p. 1218
Horne, R, & Weinman, J. (1999). Patients' beliefs about prescribed medicines and their role in adherence to treatment in chronic physical illness. Journal of Psychosomatic Research, 47(6), 555–567. https://doi.org/10.1016/s0022-3999(99)00057-4
Horne, R. 2020. Medication and treatment beliefs as determinants of treatment engagement. In: Hadler, A., Sutton, S., and Osterberg, L. eds. The wiley handbook of healthcare treatment engagement: theory, research, and clinical practice. Wiley, pp. 203–222.
Horne, R., Chapman, S.C.E., Parham, R., Freemantle, N., Forbes, A. and Cooper, V. 2013. Understanding patients' adherence-related beliefs about medicines prescribed for long-term conditions: a meta-analytic review of the Necessity-Concerns Framework. Plos One 8(12), p. e80633.
Hu, L. t., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Structural equation modeling: a multidisciplinary journal, 6(1), 1-55.
Huffman, J. C., Celano, C. M., Beach, S. R., Motiwala, S. R., & Januzzi, J. L. (2013). Depression and cardiac disease: epidemiology, mechanisms, and diagnosis.

Cardiovascular Psychiatry and Neurology, 2013, 695925. https://doi.org/10.1155/2013/695925
Hunt, S. A. (2005). ACC/AHA 2005 guideline update for the diagnosis and management of chronic HF in the adult: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to Update the 2001 Guidelines for the Evaluation and Management of HF). Journal of the American College of Cardiology, 46(6), e1-e82.
Hynynen, S., van Stralen, M., Sniehotta, F., Araújo-Soares, V., Hardeman, W., Chinapaw, M., . . . Hankonen, N. (2016). A systematic review of school-based interventions targeting physical activity and sedentary behaviour among older adolescents. International review of sport and exercise psychology, 9(1), 22-44.
Islam, R., Tinmouth, A. T., Francis, J. J., Brehaut, J. C., Born, J., Stockton, C., . . . Hyde, C. (2012). A cross-country comparison of intensive care physicians' beliefs about their transfusion behaviour: a qualitative study using the theoretical domains framework. Implementation Science, 7(1), 93.
Ivanova, E., Jensen, D., Cassoff, J., Gu, F., & Knäuper, B. (2015). Acceptance and commitment therapy improves exercise tolerance in sedentary women. Medicine and Science in Sports and Exercise, 47(6), 1251–1258. https://doi.org/10.1249/MSS.0000000000000536
Jaarsma, T., Abu-Saad, H.H., Dracup, K. and Halfens, R. 2000. Self-care behaviour of patients with heart failure. Scandinavian Journal of Caring Sciences 14(2), pp. 112–119.
Jaarsma, T., Strömberg, A., Ben Gal, T., Cameron, J., Driscoll, A., Duengen, H.-D., … Riegel, B. (2013). Comparison of self-care behaviors of heart failure patients in 15 countries worldwide. Patient Education and Counseling, 92(1), 114–120. https://doi.org/10.1016/j.pec.2013.02.017
Janssens, T. (2016). "It's all bad": Fear avoidance beliefs predict lack of differentiation between dyspnea dimensions in anticipation of exercise-related dyspnea. In 4.1 Clinical Physiology, Exercise and Functional Imaging (p. PA1577). European Respiratory Society. https://doi.org/10.1183/13993003.congress-2016.PA1577
Janssens, T., De Peuter, S., Stans, L., Verleden, G., Troosters, T., Decramer, M., & Van den Bergh, O. (2011). Dyspnea perception in COPD: association between anxiety, dyspnea-related fear, and dyspnea in a pulmonary rehabilitation program. Chest, 140(3), 618–625. https://doi.org/10.1378/chest.10-3257
Janssens, T., Van De Moortel, Z., Geidl, W., Pfeifer, K., Stenzel, N., Lehbert, N., … Von Leupoldt, A. (2018). Fear-avoidance beliefs, exercise capacity, and activity-related dyspnea during pulmonary rehabilitation in patients with COPD. In Rehabilitation and Chronic Care (p. PA3635). European Respiratory Society. https://doi.org/10.1183/13993003.congress-2018.PA3635
Jenni, J., Buckley John, P., Furze, G., Doherty, P., Linda, S., Connolly, S., & Hinton, S. (2012). The BACPR standards and core components for cardiovascular prevention and rehabilitation 2012.
Johansson, S., Wallander, M.-A., Ruigómez, A., & Rodríguez, L. G. (2002). Treatment patterns among newly diagnosed HF patients in general practice. European journal of clinical pharmacology, 57(11), 813-817.
Johnson, R. B., Onwuegbuzie, A. J., & Turner, L. A. (2007). Toward a definition of mixed methods research. Journal of mixed methods research, 1(2), 112-133.
Johnston, M., & Dixon, D. (2008). Current issues and new directions in psychology and health: What happened to behaviour in the decade of behaviour? Psychology and health, 23(5), 509-513.

Johnston, S., Liddy, C., Mill, K., & Irving, H. (2012). Building the evidence base for chronic disease self-management support interventions across Canada. Canadian Journal of Public Health, 103(6), e462-7.

Jolliffe, J., Rees, K., Taylor, R. R., Thompson, D. R., Oldridge, N., & Ebrahim, S. (2001). Exercise-based rehabilitation for coronary heart disease. The Cochrane Library.

Jolly, K., Taylor, R. S., Lip, G. Y. H., Davies, M., Davis, R., Mant, J., … Stevens, A. (2009). A randomized trial of the addition of home-based exercise to specialist heart failure nurse care: the Birmingham Rehabilitation Uptake Maximisation study for patients with Congestive Heart Failure (BRUM-CHF) study. European Journal of Heart Failure, 11(2), 205–213. https://doi.org/10.1093/eurjhf/hfn029

Jolly, K., Tayor, R. S., Lip, G. Y., Greenfield, S. M., Davies, M. K., Davis, R. C., . . . Stubley, J. (2007). Home-based exercise rehabilitation in addition to specialist HF nurse care: design, rationale and recruitment to the Birmingham Rehabilitation Uptake Maximisation study for patients with congestive HF (BRUM-CHF): a randomised controlled trial. BMC Cardiovascular Disorders, 7(1), 1.

Jöreskog, K. G., & Sörbom, D. (1993). LISREL 8: Structural equation modeling with the SIMPLIS command language: Scientific Software International.

Karoly, P., Ruehlman, L. S., Okun, M. A., Lutz, R. S., Newton, C., & Fairholme, C. (2005). Perceived self-regulation of exercise goals and interfering goals among regular and irregular exercisers: a life space analysis. Psychology of Sport and Exercise, 6(4), 427–442. https://doi.org/10.1016/j.psychsport.2004.03.004

Keteyian, S., Ellis, S., & Houston Miller, N. (2009). A dose-response analysis of patients with HF enrolled in a controlled trial investigating outcomes of exercise training (HF-ACTION). Paper presented at the American College of Cardiology Scientific Meetings.

Klaassen, F. (2020). Combining evidence over multiple individual analyses. In R. van de Schoot & M. Miočević (Eds.), Small sample size solutions: A guide for applied researchers and practitioners (pp. 126–138). Routledge. https://doi.org/10.4324/9780429273872-11

Klompstra, L., Jaarsma, T. and Strömberg, A. 2015. Physical activity in patients with heart failure: barriers and motivations with special focus on sex differences. Patient preference and adherence 9, pp. 1603–1610.

Klompstra, L., Jaarsma, T. and Strömberg, A. 2018. Self-efficacy Mediates the Relationship Between Motivation and Physical Activity in Patients With Heart Failure. The Journal of Cardiovascular Nursing 33(3), pp. 211–216.

Klompstra, L., Strömberg, A., Gastelurrutia, P., Cabanes, R., Rodriguez, M., Gonzalez, B., . . . Jaarsma, T. (2015). Physical activity in daily life in HF patients living in two European countries. Paper presented at the HF 2015, Sevilla, Spain.

Koelling, T. M., Johnson, M. L., Cody, R. J., & Aaronson, K. D. (2005). Discharge education improves clinical outcomes in patients with chronic HF. Circulation, 111(2), 179-185.

Koeneman, M. A., Chorus, A., Hopman-Rock, M., & Chinapaw, M. J. M. (2017). A novel method to promote physical activity among older adults in residential care: an exploratory field study on implicit social norms. BMC Geriatrics, 17(1), 8. https://doi.org/10.1186/s12877-016-0394-z

Kok, G., Gottlieb, N. H., Peters, G.-J. Y., Mullen, P. D., Parcel, G. S., Ruiter, R. A. C., … Bartholomew, L. K. (2016). A taxonomy of behaviour change methods: an Intervention Mapping approach. Health Psychology Review, 10(3), 297–312. https://doi.org/10.1080/17437199.2015.1077155

Kolehmainen, N., Francis, J. J., Ramsay, C. R., Owen, C., McKee, L., Ketelaar, M., & Rosenbaum, P. (2011). Participation in physical play and leisure: developing a theory-and evidence-based intervention for children with motor impairments.

BMC pediatrics, 11(1), 100.
Komajda, M., Follath, F., Swedberg, K. o., Cleland, J., Aguilar, J., Cohen-Solal, A., . . . Hobbs, R. (2003). The EuroHF Survey programme—a survey on the quality of care among patients with HF in Europe. European Heart Journal, 24(5), 464-474.
Kowalski, K., Rhodes, R., Naylor, P.-J., Tuokko, H., & MacDonald, S. (2012). Direct and indirect measurement of physical activity in older adults: a systematic review of the literature. International Journal of Behavioral Nutrition and Physical Activity, 9(1), 148.
Kramer, D. B., Jones, P. W., Rogers, T., Mitchell, S. L., & Reynolds, M. R. (2017). Patterns of physical activity and survival following cardiac resynchronization therapy implantation: the ALTITUDE activity study. Europace, 19(11), 1841–1847. https://doi.org/10.1093/europace/euw267
Krippendorff, K. (2007). Computing Krippendorff's alpha reliability. Departmental papers (ASC), 43.
Kruglanski, A. W., Shah, J. Y., Fishbach, A., Friedman, R., Chun, W. Y., & Sleeth-Keppler, D. (2018). A theory of goal systems. In The Motivated Mind (pp. 207–250). Routledge. https://doi.org/10.4324/9781315175867-6
Kwasnicka, D., Dombrowski, S. U., White, M., & Sniehotta, F. (2016). Theoretical explanations for maintenance of behaviour change: a systematic review of behaviour theories. Health Psychology Review, 10(3), 277–296. https://doi.org/10.1080/17437199.2016.1151372
Lally, P., van Jaarsveld, C. H. M., Potts, H. W. W., & Wardle, J. (2010). How are habits formed: Modelling habit formation in the real world. European Journal of Social Psychology, 40, 998–1009. doi: 10.1002/ejsp.674
Lally, P., & Gardner, B. (2013). Promoting habit formation. Health psychology review, 7(sup1), S137-S158.
Lee, H., Boo, S., Yu, J., Suh, S.-R., Chun, K.J. and Kim, J.H. 2016. Physical Functioning, Physical Activity, Exercise Self-Efficacy, and Quality of Life Among Individuals With Chronic Heart Failure in Korea: A Cross-Sectional Descriptive Study. The journal of nursing research : JNR.
Lemoine, N. P. (2019). Moving beyond noninformative priors: why and how to choose weakly informative priors in Bayesian analyses. Oikos, 128(7), 912–928. https://doi.org/10.1111/oik.05985
Lemoine, N.P. 2019. Moving beyond noninformative priors: why and how to choose weakly informative priors in Bayesian analyses. Oikos 128(7), pp. 912–928.
Leupoldt, A., Reijnders, T., Petersen, S., Stenzel, N., Schuler, M., Wittmann, M., … Schultz, K. (2017). Disease-specific fears impact outcomes of pulmonary rehabilitation in patients with COPD. Pneumologie, 71(S 01), S1–S125. https://doi.org/10.1055/s-0037-1598582
Leventhal, H, Meyer, D., & Nerenz, D. (1980). The common sense representation of illness danger. Contributions to Medical Psychology, 2, 7–30.
Leventhal, Howard, Phillips, L. A., & Burns, E. (2016). The Common-Sense Model of Self-Regulation (CSM): A dynamic framework for understanding illness self-management. Journal of Behavioral Medicine, 39(6), 935–946. https://doi.org/10.1007/s10865-016-9782-2
Lewinter, C., Doherty, P., Gale, C. P., Crouch, S., Stirk, L., Lewin, R. J., … Bland, J. M. (2015). Exercise-based cardiac rehabilitation in patients with heart failure: a meta-analysis of randomised controlled trials between 1999 and 2013. European Journal of Preventive Cardiology, 22(12), 1504–1512. https://doi.org/10.1177/2047487314559853

Lewis, M. G., & Nair, N. S. (2015). Review of applications of Bayesian meta-analysis in systematic reviews. Global Journal of Medicine and Public Health, 4(1), 1–9.
Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P., . . . Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. PLoS Med, 6(7), e1000100.
Ling, L.-H., Kistler, P. M., Kalman, J. M., Schilling, R. J., & Hunter, R. J. (2016). Comorbidity of atrial fibrillation and heart failure. Nature Reviews. Cardiology, 13(3), 131–147. https://doi.org/10.1038/nrcardio.2015.191
Lippke, S., & Ziegelmann, J. P. (2008). Theory-based health behavior change: Developing, testing, and applying theories for evidence-based interventions. Applied Psychology, 57(4), 698-716.
Liu, T.-W., Ng, S. S., Kwong, P. W., & Ng, G. Y. (2015). Fear Avoidance Behavior, Not Walking Endurance, Predicts the Community Reintegration of Community-Dwelling Stroke Survivors. Archives of Physical Medicine and Rehabilitation, 96(9), 1684–1690. https://doi.org/10.1016/j.apmr.2015.05.005
Lloyd-Jones, D. M., Larson, M. G., Leip, E. P., Beiser, A., D'agostino, R. B., Kannel, W. B., . . . Levy, D. (2002). Lifetime risk for developing congestive HF. Circulation, 106(24), 3068-3072.
Locke, E. A., & Latham, G. P. (2006). New Directions in Goal-Setting Theory. Current Directions in Psychological Science, 15(5), 265–268. https://doi.org/10.1111/j.1467-8721.2006.00449.x
Lorig, K. R., Sobel, D. S., Ritter, P. L., Laurent, D., & Hobbs, M. (2001). Effect of a self-management program on patients with chronic disease. Effective clinical practice: ECP, 4(6), 256-262.
MacCallum, R. C., & Hong, S. (1997). Power analysis in covariance structure modeling using GFI and AGFI. Multivariate behavioral research, 32(2), 193-210.
MacInnes, J. (2014). An exploration of illness representations and treatment beliefs in heart failure. Journal of Clinical Nursing, 23(9–10), 1249–1256. https://doi.org/10.1111/jocn.12307
Maestrini, D. (1951). The importance of the altered organic exchange (fatigue), of the structure and colloidal state of the fiber, for the genesis of the so-called small, insufficient contractions of the heart in failure. Il Policlinico. Sezione pratica, 58(30), 933.
Mark, M. M., & Shotland, R. L. (1987). Alternative models for the use of multiple methods. New Directions for Evaluation, 1987(35), 95-100.
Marr, D., & Poggio, T. (1976). Cooperative computation of stereo disparity. Science, 194(4262), 283–287. https://doi.org/10.1126/science.968482
Mattingly, C. 1994. The concept of therapeutic "emplotment". Social Science & Medicine 38(6), pp. 811–822.
Maynard, A., & Chalmers, I. (1997). Non-random reflections on health services research. BM J. publishings, London.
McAlister, F. A., Stewart, S., Ferrua, S., & McMurray, J. J. (2004). Multidisciplinary strategies for the management of HF patients at high risk for admission: a systematic review of randomized trials. Journal of the American College of Cardiology, 44(4), 810-819.
McBain, H., Begum, S., Rahman, S., & Mulligan, K. (2017). Barriers to and enablers of insulin self-titration in adults with Type 2 diabetes: a qualitative study. Diabetic Medicine, 34(2), 253-261.

McDonald, S., O'Brien, N., White, M., & Sniehotta, F. F. (2015). Changes in physical activity during the retirement transition: a theory-based, qualitative interview study. The International Journal of Behavioral Nutrition and Physical Activity, 12, 25. https://doi.org/10.1186/s12966-015-0186-4

McEwan, D., Harden, S. M., Zumbo, B. D., Sylvester, B. D., Kaulius, M., Ruissen, G. R., … Beauchamp, M. R. (2016). The effectiveness of multi-component goal setting interventions for changing physical activity behaviour: a systematic review and meta-analysis. Health Psychology Review, 10(1), 67–88. https://doi.org/10.1080/17437199.2015.1104258

McIntosh, C. N. (2007). Rethinking fit assessment in structural equation modelling: A commentary and elaboration on Barrett (2007). Personality and Individual Differences, 42(5), 859-867.

McMurray, J. J., Adamopoulos, S., Anker, S. D., Auricchio, A., Böhm, M., Dickstein, K., . . . Gomez-Sanchez, M. A. (2012). ESC Guidelines for the diagnosis and treatment of acute and chronic HF 2012. European journal of HF, 14(8), 803-869.

McPhee, J. S., French, D. P., Jackson, D., Nazroo, J., Pendleton, N., & Degens, H. (2016). Physical activity in older age: perspectives for healthy ageing and frailty. Biogerontology, 17(3), 567–580. https://doi.org/10.1007/s10522-016-9641-0

McSherry, L. A., Dombrowski, S. U., Francis, J. J., Murphy, J., Martin, C. M., O'Leary, J. J., & Sharp, L. (2012). 'It'sa can of worms': understanding primary care practitioners' behaviours in relation to HPV using the theoretical domains framework. Implementation Science, 7(1), 73.

Meng, K., Musekamp, G., Schuler, M., Seekatz, B., Glatz, J., Karger, G., … Faller, H. (2016). The impact of a self-management patient education program for patients with chronic heart failure undergoing inpatient cardiac rehabilitation. Patient Education and Counseling, 99(7), 1190–1197. https://doi.org/10.1016/j.pec.2016.02.010

Messick, S. (1993). Foundations of validity: meaning and consequences in psychological assessment. ETS Research Report Series, 1993(2), i-18. https://doi.org/10.1002/j.2333-8504.1993.tb01562.x

Michie, S, Atkins, L., & West, R. (2014). The behaviour change wheel. A Guide to Designing Interventions. 1st Ed. Great Britain: Silverback Publishing, 1003–1010.

Michie, S. and Prestwich, A. 2010. Are interventions theory-based? Development of a theory coding scheme. Health Psychology 29(1), pp. 1–8.

Michie, S., & Johnston, M. (2012). Theories and techniques of behaviour change: Developing a cumulative science of behaviour change: Taylor & Francis.

Michie, S., Atkins, L. and West, R. 2014. The behaviour change wheel. A guide to designing interventions. 1st ed. Great Britain: Silverback Publishing, pp. 1003–1010.

Michie, S., Johnston, M., Abraham, C., Lawton, R., Parker, D., & Walker, A. (2005). Making psychological theory useful for implementing evidence-based practice: a consensus approach. Quality and safety in health care, 14(1), 26-33.

Michie, S., Richardson, M., Johnston, M., Abraham, C., Francis, J., Hardeman, W., … Wood, C. E. (2013). The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behavior change interventions. Annals of Behavioral Medicine, 46(1), 81–95. https://doi.org/10.1007/s12160-013-9486-6

Michie, S., van Stralen, M. M., & West, R. (2011). The behaviour change wheel: a new method for characterising and designing behaviour change interventions. Implementation Science, 6(1), 42.

Michie, S., Wood, C. E., Johnston, M., Abraham, C., Francis, J., & Hardeman, W. (2015). Behaviour change techniques: the development and evaluation of a taxonomic method for reporting and describing behaviour change interventions (a suite of five studies involving consensus methods, randomised controlled trials and analysis of qualitative data). Health Technology Assessment, 19(99).

Miller, W. R. (1983). Motivational interviewing with problem drinkers. Behavioural and Cognitive Psychotherapy, 11(2), 147-172.

Miller, W. R., & Rose, G. S. (2009). Toward a theory of motivational interviewing. American psychologist, 64(6), 527.

Milne, S., Orbell, S., & Sheeran, P. (2002). Combining motivational and volitional interventions to promote exercise participation: Protection motivation theory and implementation intentions. British Journal of Health Psychology, 7(2), 163-184.

Moher, D., Jadad, A. R., Nichol, G., Penman, M., Tugwell, P., & Walsh, S. (1995). Assessing the quality of randomized controlled trials: an annotated bibliography of scales and checklists. Controlled clinical trials, 16(1), 62-73.

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Annals of internal medicine, 151(4), 264-269.

Moore, G. F., & Evans, R. E. (2017). What theory, for whom and in which context? Reflections on the application of theory in the development and evaluation of complex population health interventions. SSM - Population Health, 3, 132–135. https://doi.org/10.1016/j.ssmph.2016.12.005

Moreno-Suarez, I., Liew, S., Dembo, L. G., Larbalestier, R., & Maiorana, A. (2020). Physical Activity Is Higher in Patients with Left Ventricular Assist Device Compared with Chronic Heart Failure. Medicine and Science in Sports and Exercise, 52(1), 1–7. https://doi.org/10.1249/MSS.0000000000002104

Moss-Morris, R., Weinman, J., Petrie, K., Horne, R., Cameron, L., & Buick, D. (2002). The revised illness perception questionnaire (IPQ-R). Psychology and health, 17(1), 1-16.

Mosterd, A., & Hoes, A. W. (2007). Clinical epidemiology of HF. Heart, 93(9), 1137-1146.

Moudgil, R., & Haddad, H. (2013). Depression in heart failure. Current Opinion in Cardiology, 28(2), 249–258. https://doi.org/10.1097/HCO.0b013e32835ced80

Mulligan, K., McBain, H., Lamontagne-Godwin, F., Chapman, J., Haddad, M., Jones, J., ... & Simpson, A. (2017). Barriers and enablers of type 2 diabetes self-management in people with severe mental illness. Health Expectations.

Murphy, M., Saunders, J., Campbell, M., Jackson, B., & Berlowitz, D. (2003). The process of implementing the Stanford model chronic disease self management program: The northern hospital experience. Australian Journal of Primary Health, 9(2), 3.

National Institute for Health and Care Excellence (2003). Chronic HF: Management of chronic HF in adults in primary and secondary care. Clinical guideline [CG5]. Archived: https://www.nice.org.uk/guidance/cg5.

National Institute for Health and Care Excellence (2007). Behaviour change at population, community and individual levels (Public Health Guidance 6).   Retrieved from NICE. from http://www.nice.org.uk/Guidance/PH6.

National Institute for Health and Care Excellence. (2010). Chronic HF: the management of adults with chronic HF in primary and secondary care (partial update). (Clinical guideline 108). NICE. Chronic HF.

National Institute for Health and Care Excellence. (2016) Chronic HF in adults Quality standard [QS9] Retrieved from https://www.nice.org.uk/guidance/qs9

National Institute for Healthcare and Excellence. (2018). NICE: Overview. Chronic heart failure in adults: diagnosis and management. Guidance. Retrieved March 23, 2020, from https://www.nice.org.uk/guidance/ng106

Nelson, N., & Churilla, J. R. (2015). Physical activity, fear avoidance, and chronic non-specific pain: A narrative review. Journal of Bodywork and Movement Therapies, 19(3), 494–499. https://doi.org/10.1016/j.jbmt.2015.02.001

Newman, D. A., Jacobs, R. R., & Bartram, D. (2007). Choosing the best method for local validity estimation: Relative accuracy of meta-analysis versus a local study versus Bayes-analysis. Journal of Applied Psychology, 92(5), 1394–1413. https://doi.org/10.1037/0021-9010.92.5.1394

Nicholson, S. L., Donaghy, M., Johnston, M., Sniehotta, F. F., van Wijck, F., Johnston, D., . . . Mead, G. (2014). A qualitative theory guided analysis of stroke survivors' perceived barriers and facilitators to physical activity. Disability and rehabilitation, 36(22), 1857-1868.

Norberg, E. B., Boman, K., & Löfgren, B. (2008). Activities of daily living for old persons in primary health care with chronic HF. Scandinavian journal of caring sciences, 22(2), 203-210.

Nyman, S. R., Adamczewska, N., & Howlett, N. (2017). Systematic review of behaviour change techniques to promote participation in physical activity among people with dementia. British Journal of Health Psychology.

O'Cathain, A., Croot, L., Sworn, K., Duncan, E., Rousseau, N., Turner, K., … Hoddinott, P. (2019). Taxonomy of approaches to developing interventions to improve health: a systematic methods overview. Pilot and Feasibility Studies, 5, 41. https://doi.org/10.1186/s40814-019-0425-6

O'Connor, C. M., Whellan, D. J., Lee, K. L., Keteyian, S. J., Cooper, L. S., Ellis, S. J., … HF-ACTION Investigators. (2009). Efficacy and safety of exercise training in patients with chronic heart failure: HF-ACTION randomized controlled trial. The Journal of the American Medical Association, 301(14), 1439–1450. https://doi.org/10.1001/jama.2009.454

O'Doherty, J. P., Cockburn, J., & Pauli, W. M. (2017). Learning, reward, and decision making. Annual Review of Psychology, 68, 73–100. https://doi.org/10.1146/annurev-psych-010416-044216

O'Donnell, J., Smith-Byrne, K., Velardo, C., Conrad, N., Salimi-Khorshidi, G., Doherty, A., … Rahimi, K. (2020). Self-reported and objectively measured physical activity in people with and without chronic heart failure: UK Biobank analysis. Open Heart, 7(1), e001099. https://doi.org/10.1136/openhrt-2019-001099

O'Donnell, J., Smith-Byrne, K., Velardo, C., et al. 2020. Self-reported and objectively measured physical activity in people with and without chronic heart failure: UK Biobank analysis. Open heart 7(1), p. e001099.

Ogden, J. (2004). Health psychology: A textbook (3rd ed.): Maidenhead: UK: Open University Press.

Oka, R.K., Gortner, S.R., Stotts, N.A. and Haskell, W.L. 1996. Predictors of physical activity in patients with chronic heart failure secondary to either ischemic or idiopathic dilated cardiomyopathy. The American Journal of Cardiology 77(2), pp. 159–163.

OpenStax College. (2013). Anatomy & physiology. Houston, TX: OpenStax CNX. Retrieved from http://cnx.org/content/col11496/latest/.

Oudejans, I., Mosterd, A., Bloemen, J. A., Valk, M. J., Velzen, E., Wielders, J. P., . . . Hoes, A. W. (2011). Clinical evaluation of geriatric outpatients with suspected HF: value of symptoms, signs, and additional tests. European journal of HF, 13(5), 518-527.

Padgett, D. K. (1998). Does the glove really fit? qualitative research and clinical social work practice. Social Work/Maatskaplike Werk, 43(4), 373–381. https://doi.org/10.1093/sw/43.4.373

Padgett, D.K. 1998. Does the glove really fit? qualitative research and clinical social

work practice. Social Work/Maatskaplike Werk 43(4), pp. 373–381.
Page, M. J., McKenzie, J. E., & Higgins, J. P. T. (2018). Tools for assessing risk of reporting biases in studies and syntheses of studies: a systematic review. BMJ Open, 8(3), e019703. https://doi.org/10.1136/bmjopen-2017-019703
Palminteri, S., Khamassi, M., Joffily, M., & Coricelli, G. (2015). Contextual modulation of value signals in reward and punishment learning. Nature Communications, 6, 8096. https://doi.org/10.1038/ncomms9096
Palminteri, S., Wyart, V., & Koechlin, E. (2017). The importance of falsification in computational cognitive modeling. Trends in Cognitive Sciences, 21(6), 425–433. https://doi.org/10.1016/j.tics.2017.03.011
Panic, N., Leoncini, E., De Belvis, G., Ricciardi, W., & Boccia, S. (2013). Evaluation of the endorsement of the preferred reporting items for systematic reviews and meta-analysis (PRISMA) statement on the quality of published systematic review and meta-analyses. PloS one, 8(12), e83138.
Pearl, J. (2009). Causality. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511803161
Petersen, S., Rayner, M., & Wolstenholme, J. (2002). Coronary heart disease statistics: HF supplement 2002 edition.
Peto, R. (1987). Why do we need systematic overviews of randomized trials?(Transcript of an oral presentation, modified by the editors). Statistics in medicine, 6(3), 233-240.
Piano, M. R., Bondmass, M., & Schwertz, D. W. (1998). The molecular and cellular pathophysiology of HF. Heart & Lung: The Journal of Acute and Critical Care, 27(1), 3-19.
Pihl, E., Fridlund, B., & Mårtensson, J. (2011). Patients' experiences of physical limitations in daily life activities when suffering from chronic heart failure; a phenomenographic analysis. Scandinavian Journal of Caring Sciences, 25(1), 3–11. https://doi.org/10.1111/j.1471-6712.2010.00780.x
Polit, D. F., & Beck, C. T. (2004). Nursing research: Principles and methods: Lippincott Williams & Wilkins.
Ponikowski, P., Voors, A. A., Anker, S. D., Bueno, H., Cleland, J. G. F., Coats, A. J. S., … ESC Scientific Document Group. (2016). 2016 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure: The Task Force for the diagnosis and treatment of acute and chronic heart failure of the European Society of Cardiology (ESC)Developed with the special contribution of the Heart Failure Association (HFA) of the ESC. European Heart Journal, 37(27), 2129–2200. https://doi.org/10.1093/eurheartj/ehw128
Popper, K. (1963). Conjectures and Refutations: The Growth of Scientific Knowledge (Routledge Classics).
Powers, M. B., Zum Vorde Sive Vording, M. B., & Emmelkamp, P. M. G. (2009). Acceptance and commitment therapy: a meta-analytic review. Psychotherapy and Psychosomatics, 78(2), 73–80. https://doi.org/10.1159/000190790
Pozehl, B. J., McGuire, R., Duncan, K., Kupzyk, K., Norman, J., Artinian, N. T., … Keteyian, S. J. (2018). Effects of the HEART camp trial on adherence to exercise in patients with heart failure. Journal of Cardiac Failure, 24(10), 654–660. https://doi.org/10.1016/j.cardfail.2018.06.007
Presseau, J., Tait, R. I., Johnston, D. W., Francis, J. J., & Sniehotta, F. F. (2013). Goal conflict and goal facilitation as predictors of daily accelerometer-assessed physical activity. Health Psychology, 32(12), 1179–1187. https://doi.org/10.1037/a0029430

Presseau, J., Tait, R.I., Johnston, D.W., Francis, J.J. and Sniehotta, F.F. 2013. Goal conflict and goal facilitation as predictors of daily accelerometer-assessed physical activity. Health Psychology 32(12), pp. 1179–1187.
Pressler, S. J., Subramanian, U., Shaw, R. M., Meyer, L. E., Stoudemire, K., & Gradus-Pizlo, I. (2008). Research in patients with heart failure: challenges in recruitment. American Journal of Critical Care, 17(3), 198-203.
Prince, S. A., Adamo, K. B., Hamel, M. E., Hardt, J., Gorber, S. C., & Tremblay, M. (2008). A comparison of direct versus self-report measures for assessing physical activity in adults: a systematic review. International Journal of Behavioral Nutrition and Physical Activity, 5(1), 56.
Prinsen, C. A. C., Mokkink, L. B., Bouter, L. M., Alonso, J., Patrick, D. L., de Vet, H. C. W., & Terwee, C. B. (2018). COSMIN guideline for systematic reviews of patient-reported outcome measures. Quality of Life Research, 27(5), 1147–1157. https://doi.org/10.1007/s11136-018-1798-3
Prochaska, J. O., & DiClemente, C. C. (1986). Toward a comprehensive model of change Treating addictive behaviors (pp. 3-27): Springer.
Rebar, A. L., Gardner, B., Rhodes, R. E., & Verplanken, B. (2018). The measurement of habit. In The psychology of habit (pp. 31-49). Springer, Cham.
Rebar, A. L., Rhodes, R. E., & Gardner, B. (2019). How we are misinterpreting physical activity intention - behavior relations and what to do about it. The International Journal of Behavioral Nutrition and Physical Activity, 16(1), 71. https://doi.org/10.1186/s12966-019-0829-y
Rich, M. W., Beckham, V., Wittenberg, C., Leven, C. L., Freedland, K. E., & Carney, R. M. (1995). A multidisciplinary intervention to prevent the readmission of elderly patients with congestive HF. New England Journal of Medicine, 333(18), 1190-1195.
Richardson, M., Khouja, C. L., Sutcliffe, K., & Thomas, J. (2019). Using the theoretical domains framework and the behavioural change wheel in an overarching synthesis of systematic reviews. BMJ open, 9(6), e024950.
Riegel, B., Dickson, V. V., Lee, C. S., Daus, M., Hill, J., Irani, E., … Bove, A. (2018). A mixed methods study of symptom perception in patients with chronic heart failure. Heart & Lung : The Journal of Critical Care, 47(2), 107–114. https://doi.org/10.1016/j.hrtlng.2017.11.002
Risendal, B. C., Dwyer, A., Lorig, K., Seidel, R. W., Coombs, L., & Ory, M. G. (2015). Meeting the public health challenge of cancer surviorship: results of the evaluation of the chronic disease self-management program (CDSMP) for cancer survivors. Frontiers in public health, 3, 214.
Frontiers in Public Health, 2, 214. https://doi.org/10.3389/fpubh.2014.00214
Risk of Bias 2 (RoB 2) tool | Cochrane Methods. (n.d.). Retrieved March 1, 2020, from https://methods.cochrane.org/risk-bias-2
Roberts, K. A., Dixon-Woods, M., Fitzpatrick, R., Abrams, K. R., & Jones, D. R. (2002). Factors affecting uptake of childhood immunisation: a Bayesian synthesis of qualitative and quantitative evidence. The Lancet, 360(9345), 1596–1599. https://doi.org/10.1016/S0140-6736(02)11560-1
Roger, V. L. (2010). The HF epidemic. International journal of environmental research and public health, 7(4), 1807-1830.
Rogers, C., R (1957) The Necessary and Sufficient Conditions of Therapeutic Personality Change. Journal of Consulting Psychology, Vol. 21, pp. 95–103.
Rossman, G. B., & Wilson, B. L. (1985). Numbers and words combining quantitative and qualitative methods in a single large-scale evaluation study. Evaluation review, 9(5), 627-643.

Rothman, K. J., Lash, T. L., & Greenland, S. (2008). Modern Epidemiology.
Rothman, K.J., Lash, T.L. and Greenland, S. 2008. Modern Epidemiology.
Rovniak, L. S., Anderson, E. S., Winett, R. A., & Stephens, R. S. (2002). Social cognitive determinants of physical activity in young adults: a prospective structural equation analysis. Annals of Behavioral Medicine, 24(2), 149–156. https://doi.org/10.1207/S15324796ABM2402_12
Rubak, S., Sandbæk, A., Lauritzen, T., & Christensen, B. (2005). Motivational interviewing: a systematic review and meta-analysis. Br J Gen Pract, 55(513), 305-312.
Rushton, C. A., Satchithananda, D. K., Jones, P. W., & Kadam, U. T. (2015). Non-cardiovascular comorbidity, severity and prognosis in non-selected heart failure populations: A systematic review and meta-analysis. International Journal of Cardiology, 196, 98–106. https://doi.org/10.1016/j.ijcard.2015.05.180
Sabaté, E. (Ed.). (2003). Adherence to long-term therapies: evidence for action. World Health Organization.
Sagar, V. A., Davies, E. J., Briscoe, S., Coats, A. J. S., Dalal, H. M., Lough, F., … Taylor, R. S. (2015). Exercise-based rehabilitation for heart failure: systematic review and meta-analysis. Open Heart, 2(1), e000163. https://doi.org/10.1136/openhrt-2014-000163
Sallis, J. F., Grossman, R. M., Pinski, R. B., Patterson, T. L., & Nader, P. R. (1987). The development of scales to measure social support for diet and exercise behaviors. Preventive medicine, 16(6), 825-836.
Samdal, G. B., Eide, G. E., Barth, T., Williams, G., & Meland, E. (2017). Effective behaviour change techniques for physical activity and healthy eating in overweight and obese adults; systematic review and meta-regression analyses. International Journal of Behavioral Nutrition and Physical Activity, 14(1), 42.
Sanderson, S., Tatt, I. D., & Higgins, J. P. T. (2007). Tools for assessing quality and susceptibility to bias in observational studies in epidemiology: a systematic review and annotated bibliography. International Journal of Epidemiology, 36(3), 666–676. https://doi.org/10.1093/ije/dym018
Santiago de Araújo Pio, C., Chaves, G. S., Davies, P., Taylor, R. S., & Grace, S. L. (2019). Interventions to promote patient utilisation of cardiac rehabilitation. Cochrane Database of Systematic Reviews, 2, CD007131 https://doi.org/10.1002/14651858.CD007131.pub4
Santos, G. C., Liljeroos, M., Dwyer, A. A., Jaques, C., Girard, J., Strömberg, A., … Schäfer-Keller, P. (2020). Symptom perception in heart failure: a scoping review on definition, factors and instruments. European Journal of Cardiovascular Nursing : Journal of the Working Group on Cardiovascular Nursing of the European Society of Cardiology, 19(2), 100–117. https://doi.org/10.1177/1474515119892797
Scheibehenne, B., & Pachur, T. (2015). Using Bayesian hierarchical parameter estimation to assess the generalizability of cognitive models of choice. Psychonomic Bulletin & Review, 22(2), 391–407. https://doi.org/10.3758/s13423-014-0684-4
Scholz, U., Sniehotta, F. F., & Schwarzer, R. (2005). Predicting physical exercise in cardiac rehabilitation: The role of phase-specific self-efficacy beliefs. Journal of Sport and Exercise Psychology, 27(2), 135-151.
Schumacker, R. E., & Lomax, R. G. (2004). A beginner's guide to structural equation modeling: Psychology Press.
Schwarzer, R. (2016). Health action process approach (HAPA) as a theoretical framework to understand behavior change. Actualidades En Psicología, 30(121), 119. https://doi.org/10.15517/ap.v30i121.23458
Schwarzer, R., & Renner, B. (2000). Social-cognitive predictors of health behavior: action self-efficacy and coping self-efficacy. Health Psychology, 19(5), 487.

Sekhon, M., Cartwright, M., & Francis, J. J. (2017). Acceptability of healthcare interventions: an overview of reviews and development of a theoretical framework. BMC Health Services Research, 17(1), 88. https://doi.org/10.1186/s12913-017-2031-8

Shea, B., Moher, D., Graham, I., Pham, B., & Tugwell, P. (2002). A comparison of the quality of Cochrane reviews and systematic reviews published in paper-based journals. Evaluation & the health professions, 25(1), 116-129.

Sheeran, P., & Orbell, S. (1999). Implementation intentions and repeated behaviour: augmenting the predictive validity of the theory of planned behaviour. European Journal of Social Psychology, 29(2–3), 349–369. https://doi.org/10.1002/(SICI)1099-0992(199903/05)29:2/3<349::AID-EJSP931>3.0.CO;2-Y

Shephard, R. J. (2003). Limits to the measurement of habitual physical activity by questionnaires. British journal of sports medicine, 37(3), 197-206.

Shiffrin, R. M., & Schneider, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending and a general theory. Psychological Review, 84(2), 127–190. https://doi.org/10.1037/0033-295X.84.2.127

Shikano, S. (2019). Hypothesis testing in the bayesian framework. Swiss Political Science Review, 25(3), 288–299. https://doi.org/10.1111/spsr.12375

Shoemaker, M. J., Curtis, A. B., Vangsnes, E., & Dickinson, M. G. (2013). Clinically meaningful change estimates for the six-minute walk test and daily activity in individuals with chronic HF. Cardiopulmonary physical therapy journal, 24(3), 21-29.

Smeulders, E. S. T. F., van Haastregt, J. C. M., Ambergen, T., Janssen-Boyne, J. J. J., van Eijk, J. T. M., & Kempen, G. I. J. M. (2009). The impact of a self-management group programme on health behaviour and healthcare utilization among congestive heart failure patients. European Journal of Heart Failure, 11(6), 609–616. https://doi.org/10.1093/eurjhf/hfp047

Sniehotta, F. F., Scholz, U., & Schwarzer, R. (2005). Bridging the intention–behaviour gap: Planning, self-efficacy, and action control in the adoption and maintenance of physical exercise. Psychology & Health, 20(2), 143–160. https://doi.org/10.1080/08870440512331317670

Snipelisky, D., Kelly, J., Levine, J.A., et al. 2017. Accelerometer-Measured Daily Activity in Heart Failure With Preserved Ejection Fraction: Clinical Correlates and Association With Standard Heart Failure Severity Indices. Circulation. Heart Failure 10(6), p. e003878.

Song, F., Parekh-Bhurke, S., Hooper, L., Loke, Y. K., Ryder, J. J., Sutton, A. J., . . . Harvey, I. (2009). Extent of publication bias in different categories of research cohorts: a meta-analysis of empirical studies. BMC Medical research methodology, 9(1), 79.

Spiegelhalter, D. J., Abrams, K. R., & Myles, J. P. (2003). Bayesian Approaches to Clinical Trials and Health-Care Evaluation. Chichester, UK: John Wiley & Sons, Ltd. https://doi.org/10.1002/0470092602

Sterne, J. A., Egger, M., & Smith, G. D. (2001). Investigating and dealing with publication and other biases in meta-analysis. BMJ: British Medical Journal, 323(7304), 101.

Stroup, D. F., Berlin, J. A., Morton, S. C., Olkin, I., Williamson, G. D., Rennie, D., … Thacker, S. B. (2000). Meta-analysis of observational studies in epidemiology: a proposal for reporting. Meta-analysis Of Observational Studies in Epidemiology (MOOSE) group. The Journal of the American Medical Association, 283(15), 2008–2012. https://doi.org/10.1001/jama.283.15.2008

Suppes, P., & Zanotti, M. (1981). When Are Probabilistic Explanations Possible? Synthese, 48(2), 191–199.

Sutton, A. J., Duval, S., Tweedie, R., Abrams, K. R., & Jones, D. R. (2000). Empirical assessment of effect of publication bias on meta-analyses. BMJ: British Medical Journal: , 320(7249), 1574-1577.
Symon, G., & Cassell, C. (2012). Qualitative organizational research: core methods and current challenges: Sage.
Tashakkori, A., & Teddlie, C. (2003). Handbook on mixed methods in the behavioral and social sciences: Thousand Oaks, CA: Sage.
Tavender, E. J., Bosch, M., Gruen, R. L., Green, S. E., Knott, J., Francis, J. J., ... & O'Connor, D. A. (2014). Understanding practice: the factors that influence management of mild traumatic brain injury in the emergency department-a qualitative study using the Theoretical Domains Framework. Implementation Science, 9(1), 8.
Taylor, C. J., Roalfe, A. K., Iles, R., & Hobbs, F. D. (2012). Ten-year prognosis of HF in the community: follow-up data from the Echocardiographic Heart of England Screening (ECHOES) study. European journal of HF, 14(2), 176-184.
Taylor, N., Lawton, R., & Conner, M. (2013). Development and initial validation of the determinants of physical activity questionnaire. International Journal of Behavioral Nutrition and Physical Activity, 10(1), 74.
Taylor, R. S., Long, L., Mordi, I. R., Madsen, M. T., Davies, E. J., Dalal, H., … Zwisler, A.-D. (2019). Exercise-Based Rehabilitation for Heart Failure: Cochrane Systematic Review, Meta-Analysis, and Trial Sequential Analysis. JACC. Heart Failure, 7(8), 691–705. https://doi.org/10.1016/j.jchf.2019.04.023
Taylor, R. S., Sagar, V. A., Davies, E. J., Briscoe, S., Coats, A., Dalal, H., . . . Singh, S. (2014). Exercise-based rehabilitation for HF. Cochrane Database Syst Rev, 4(4).
Taylor, R.S., & Anderson. (2015). Cochrane corner: cardiac rehabilitation for people with heart disease. Heart, heartjnl-2015-307778.
Telecare_Services_Association. (2017). What is Telehealth? . Retrieved from https://www.tsa-voice.org.uk/consumer-services/what-is-telehealth
Terwee, C. B., Prinsen, C. A. C., Chiarotto, A., Westerman, M. J., Patrick, D. L., Alonso, J., … Mokkink, L. B. (2018). COSMIN methodology for evaluating the content validity of patient-reported outcome measures: a Delphi study. Quality of Life Research, 27(5), 1159–1170. https://doi.org/10.1007/s11136-018-1829-0
Thaler, R. H., & Sunstein, C. R. (2008). Nudge: improving decisions about health, wealth, and happiness.
Thoemmes, F., MacKinnon, D. P., & Reiser, M. R. (2010). Power analysis for complex mediational designs using Monte Carlo methods. Structural Equation Modeling, 17(3), 510-534.
Thompson, C., McCaughan, D., Cullum, N., Sheldon, T. A., & Raynor, P. (2004). Increasing the visibility of coding decisions in team-based qualitative research in nursing. International Journal of Nursing Studies, 41(1), 15–20. https://doi.org/10.1016/j.ijnurstu.2003.03.001
Thompson, D. R., Bowman, G. S., Kitson, A. L., de Bono, D. P., & Hopkins, A. (1997). Cardiac rehabilitation services in England and Wales: a national survey. International journal of cardiology, 59(3), 299-304.
Thompson, S. G. (1994). Why sources of heterogeneity in meta-analysis should be investigated. BMJ: British Medical Journal, 309(6965), 1351.
Tierney, S., Elwers, H., Sange, C., Mamas, M., Rutter, M. K., Gibson, M., … Deaton, C. (2011). What influences physical activity in people with heart failure?: a qualitative study. International Journal of Nursing Studies, 48(10), 1234–1243. https://doi.org/10.1016/j.ijnurstu.2011.03.003

Tierney, S., Mamas, M., Skelton, D., Woods, S., Rutter, M. K., Gibson, M., . . . Deaton, C. (2011). What can we learn from patients with HF about exercise adherence? A systematic review of qualitative papers. Health Psychology, 30(4), 401.

Tierney, S., Mamas, M., Woods, S., et al. 2012. What strategies are effective for exercise adherence in heart failure? A systematic review of controlled studies. Heart failure reviews 17(1), pp. 107–115.

Tomioka, M., Braun, K. L., Compton, M., & Tanoue, L. (2012). Adapting Stanford's Chronic Disease Self-Management Program to Hawaii's multicultural population. The Gerontologist, 52(1), 121–132. https://doi.org/10.1093/geront/gnr054

Tomita, M. R., Tsai, B.-M., Fisher, N. M., Kumar, N. A., Wilding, G. E., & Naughton, B. J. (2008). Improving adherence to exercise in patients with heart failure through internet-based self-management. Journal of the American Geriatrics Society, 56(10), 1981–1983. https://doi.org/10.1111/j.1532-5415.2008.01865.x

Toomey, E., Hardeman, W., Hankonen, N., Byrne, M., McSharry, J., Matvienko-Sikar, K., & Lorencatto, F. (2020). Focusing on fidelity: narrative review and recommendations for improving intervention fidelity within trials of health behaviour change interventions. Health Psychology and Behavioral Medicine, 8(1), 132–151. https://doi.org/10.1080/21642850.2020.1738935

Tversky, A., & Kahneman, D. (1974). Judgment under Uncertainty: Heuristics and Biases. Science, 185(4157), 1124–1131. https://doi.org/10.1126/science.185.4157.1124

van Aert, R. C. M., & Jackson, D. (2019). A new justification of the Hartung-Knapp method for random-effects meta-analysis based on weighted least squares regression. Research Synthesis Methods, 10(4), 515–527. https://doi.org/10.1002/jrsm.1356

van de Schoot, R., & Miočević, M. (Eds.). (2020). Small sample size solutions: A guide for applied researchers and practitioners. Routledge. https://doi.org/10.4324/9780429273872

van den Berg-Emons, R., Balk, A., Bussmann, H., & Stam, H. (2004). Does aerobic training lead to a more active lifestyle and improved quality of life in patients with chronic heart failure? European Journal of Heart Failure, 6(1), 95–100. https://doi.org/10.1016/j.ejheart.2003.10.005

van der Wal, M.H.L., Jaarsma, T., Moser, D.K., Veeger, N.J.G.M., van Gilst, W.H. and van Veldhuisen, D.J. 2006. Compliance in heart failure patients: the importance of knowledge and beliefs. European Heart Journal 27(4), pp. 434–440.

van der Wal, M.H.L., van Veldhuisen, D.J., Veeger, N.J.G.M., Rutten, F.H. and Jaarsma, T. 2010. Compliance with non-pharmacological recommendations and outcome in heart failure patients. European Heart Journal 31(12), pp. 1486–1493.

van Rooij, I., & Baggio, G. (2020). Theory before the test: How to build high-verisimilitude explanatory theories in psychological science. https://doi.org/10.31234/osf.io/7qbpr

van Rooij, I., & Blokpoel, M. (2020). Formalizing verbal theories: A tutorial by dialogue. https://doi.org/10.31234/osf.io/r2zqy

VandenBos, G. R. (2007). APA dictionary of psychology: American Psychological Association.

Viceconti, M. (2011). A tentative taxonomy for predictive models in relation to their falsifiability. Philosophical Transactions. Series A, Mathematical, Physical, and Engineering Sciences, 369(1954), 4149–4161. https://doi.org/10.1098/rsta.2011.0227

Viechtbauer, W. (2010). Conducting Meta-Analyses in R with the metafor Package. Journal of Statistical Software, 36(3). https://doi.org/10.18637/jss.v036.i03

Viswanathan, M., Berkman, N. D., Dryden, D. M., & Hartling, L. (2013). Assessing risk of bias and confounding in observational studies of interventions or exposures: further

development of the RTI item bank. Rockville (MD): Agency for Healthcare Research and Quality (US).
Vlaeyen, J. W. S., Crombez, G., & Linton, S. J. (2016). The fear-avoidance model of pain. Pain, 157(8), 1588–1589. https://doi.org/10.1097/j.pain.0000000000000574
von Elm, E., Altman, D. G., Egger, M., Pocock, S. J., Gøtzsche, P. C., Vandenbroucke, J. P., & STROBE Initiative. (2007). Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. BMJ (Clinical Research Ed.), 335(7624), 806–808. https://doi.org/10.1136/bmj.39335.541782.AD
Vos, T., Allen, C., & Arora, M. (2016). Global, regional, and national incidence, prevalence, and years lived with disability for 310 diseases and injuries, 1990-2015: a systematic analysis for the Global Burden of Disease Study 2015. The Lancet, 388(10053), 1545–1602. https://doi.org/10.1016/S0140-6736(16)31678-6
Wei, L., Champman, S., Li, X., Li, X., Li, S., Chen, R., … Horne, R. (2017). Beliefs about medicines and non-adherence in patients with stroke, diabetes mellitus and rheumatoid arthritis: a cross-sectional study in China. BMJ Open, 7(10), e017293. https://doi.org/10.1136/bmjopen-2017-017293
Weinman, J.A. and Petrie, K.J. 1997. Perceptions of health and illness. Perceptions of health and illness, pp. 1–17.
Wen, C. P., Wai, J. P. M., Tsai, M. K., Yang, Y. C., Cheng, T. Y. D., Lee, M.-C., … Wu, X. (2011). Minimum amount of physical activity for reduced mortality and extended life expectancy: a prospective cohort study. The Lancet, 378(9798), 1244–1253. https://doi.org/10.1016/S0140-6736(11)60749-6
Werhahn, S. M., Dathe, H., Rottmann, T., Franke, T., Vahdat, D., Hasenfuß, G., & Seidler, T. (2019). Designing meaningful outcome parameters using mobile technology: a new mobile application for telemonitoring of patients with heart failure. ESC Heart Failure, 6(3), 516–525. https://doi.org/10.1002/ehf2.12425
West, R., Godinho, C. A., Bohlen, L. C., Carey, R. N., Hastings, J., Lefevre, C. E., & Michie, S. (2019). Development of a formal system for representing behaviour-change theories. Nature human behaviour, 3(5), 526-536.
Wheaton, B., Muthen, B., Alwin, D. F., & Summers, G. F. (1977). Assessing reliability and stability in panel models. Sociological methodology, 8, 84-136.
Whellan, D. J., O'Connor, C. M., Lee, K. L., Keteyian, S. J., Cooper, L. S., Ellis, S. J., . . . Blumenthal, J. A. (2007). HF and a controlled trial investigating outcomes of exercise training (HF-ACTION): design and rationale. American heart journal, 153(2), 201-211.
Willenheimer, R., Erhardt, L., Cline, C., Rydberg, E., & Israelsson, B. (1998). Exercise training in heart failure improves quality of life and exercise capacity. European Heart Journal, 19(5), 774–781. https://doi.org/10.1053/euhj.1997.0853
Willenheimer, R., Rydberg, E., Cline, C., Broms, K., Hillberger, B., Öberg, L., & Erhardt, L. (2001). Effects on quality of life, symptoms and daily activity 6 months after termination of an exercise training programme in HF patients. International journal of cardiology, 77(1), 25-31.
Williams, B. A. (2017). The clinical epidemiology of fatigue in newly diagnosed HF. BMC Cardiovascular Disorders, 17(1), 122.
Williams, S., & French, D. (2011). What are the most effective intervention techniques for changing physical activity self-efficacy and physical activity behaviour—and are they the same? Health education research, 26(2), 308-322.
Wilson, K., Senay, I., Durantini, M., Sánchez, F., Hennessy, M., Spring, B., & Albarracín, D. (2015). When it comes to lifestyle recommendations, more is sometimes less: A meta-analysis of theoretical assumptions underlying the effectiveness of interventions

promoting multiple behavior domain change. *Psychological Bulletin, 141*(2), 474-509. https://doi.org/10.1037/a0038295
Witham, M. D., Gray, J. M., Argo, I. S., Johnston, D. W., Struthers, A. D., & McMurdo, M. E. T. (2005). Effect of a seated exercise program to improve physical function and health status in frail patients > or = 70 years of age with heart failure. The American Journal of Cardiology, 95(9), 1120–1124. https://doi.org/10.1016/j.amjcard.2005.01.031
Witham, M.D., Argo, I.S., Johnston, D.W., Struthers, A.D. and McMurdo, M.E.T. 2006. Predictors of exercise capacity and everyday activity in older heart failure patients. European Journal of Heart Failure 8(2), pp. 203–207.
World Health Organisation. Global Strategy on Diet, Physical Activity and Health: Physical Activity. Retrieved from http://www.who.int/dietphysicalactivity/pa/en/
Yancy, C. W., Jessup, M., Bozkurt, B., Butler, J., Casey, D. E., Drazner, M. H., . . . Januzzi, J. L. (2013). 2013 ACCF/AHA guideline for the management of HF: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. Journal of the American College of Cardiology, 62(16), e147-e239.
Yeh, G. Y., McCarthy, E. P., Wayne, P. M., Stevenson, L. W., Wood, M. J., Forman, D., … Phillips, R. S. (2011). Tai chi exercise in patients with chronic heart failure: a randomized clinical trial. Archives of Internal Medicine, 171(8), 750–757. https://doi.org/10.1001/archinternmed.2011.150
Yohannes, A. M., Junkes-Cunha, M., Smith, J., & Vestbo, J. (2017). Management of dyspnea and anxiety in chronic obstructive pulmonary disease: A critical review. Journal of the American Medical Directors Association, 18(12), 1096.e1-1096.e17. https://doi.org/10.1016/j.jamda.2017.09.007
Young, L., Hertzog, M., & Barnason, S. (2016). Effects of a home-based activation intervention on self-management adherence and readmission in rural heart failure patients: the PATCH randomized controlled trial. BMC Cardiovascular Disorders, 16(1), 176. https://doi.org/10.1186/s12872-016-0339-7
Yuan, K.-H. (2005). Fit indices versus test statistics. Multivariate behavioral research, 40(1), 115-148.
Zhang, C.-Q., Chung, P.-K., Zhang, R., & Schüz, B. (2019). Socioeconomic Inequalities in Older Adults' Health: The Roles of Neighborhood and Individual-Level Psychosocial and Behavioral Resources. Frontiers in Public Health, 7, 318. https://doi.org/10.3389/fpubh.2019.00318
Zhang, C.-Q., Zhang, R., Schwarzer, R., & Hagger, M. S. (2019). A meta-analysis of the health action process approach. Health Psychology, 38(7), 623–637. https://doi.org/10.1037/hea0000728
Zwisler, A.-D., Norton, R. J., Dean, S. G., Dalal, H., Tang, L. H., Wingham, J., & Taylor, R. S. (2016). Home-based cardiac rehabilitation for people with HF: A systematic review and meta-analysis. International journal of cardiology, 221, 963-969.