Olander, E. K., & Eves, F. F. (2011). Elevator availability and its impact on stair use in a workplace. *Journal of Environmental Psychology, 31*(2), 200-206.

Abstract

Consistent success in encouraging stair climbing on public access staircases contrasts with equivocal evidence for effectiveness in worksites. This paper tests whether contextual factors may affect stair/elevator choice. The study investigated the impact of elevator availability, pedestrian traffic (number using the elevator and stairs per minute), building occupancy (total individuals in the building) and time of day on stair ascent and descent in a workplace. Stair and elevator choices were monitored by automatic counters every weekday during two phases. In a natural experiment, days with four available elevators were compared with days when three elevators were available. Stair use increased for three elevators compared to four. Increasing building occupancy was associated with increased stair use, whilst increasing pedestrian traffic and time of day was associated with reduced stair use. A follow-up study revealed complimentary effects of building occupancy and time of day on elevator waiting times, indicating that increased stair use by contextual factors reflects increased elevator waiting times. In contrast, shorter waiting times are likely when momentary pedestrian traffic is high and later in the day. Crucially, the magnitude of the effects of these contextual factors was ten times larger than previously reported effects of stair climbing interventions.

Keywords; Stair use; Worksite; Physical Activity

1. Introduction

Stair climbing in the workplace has been associated with numerous health benefits including decreased risk for cardiovascular disease (Boreham, Kennedy, Murphy, Tully, Wallace et al., 2005; Kennedy, Boreham, Murphy, Young & Mutrie, 2007; Meyer et al., 2010). Stairs are available in most workplaces and increased stair climbing at work is a current public health target (Department of Health, 2005; U.S. Department of Health and Human Services, 2008). To increase stair climbing, most interventions have employed point-of-choice prompts to encourage employees to take the stairs for their health (e.g. Eves, Webb & Mutrie, 2006; Kerr, Eves & Carroll, 2001a; Marshall, Bauman, Patch, Wilson & Chen, 2002; Olander & Eves, in press), with a second approach adding changes to the appearance of the stairwell (Boutelle, Jeffery, Murray & Schmitz, 2001; Kerr, Yore, Ham & Dietz, 2004). Despite numerous successful interventions on public access staircases, however, the evidence for effectiveness in worksites is equivocal (Eves, 2008; 2010; Eves & Webb, 2006). Thus, an average increase for stair climbing of +5.9% for public access settings involving choice between stairs and an escalator contrasts markedly with a +0.1% increase for stair use, i.e. ascent and descent combined, when pedestrians choose between stairs and an elevator (Eves, 2010; Soler et al., 2010). From a public health perspective, the equivocal evidence for effectiveness of interventions in worksites is problematic; regular stair climbing provides the greatest dividend and worksites are a plausible location for its occurrence. Contextual factors associated with the choice between stairs and an elevator may be important and this paper assesses their direction and magnitude. Minute-by-minute measurements of the number of people in the building and pedestrian traffic at the ground floor provide new insights into factors influencing stair use in workplaces.

Recent approaches to physical activity promotion have encompassed a broader range of potential influences than traditionally studied intra-individual processes. Ecological frameworks consider the social and physical environment, in addition to individual factors (Frank, Saelens, Powell, Chapman, 2007; Giles-Corti & Donovan, 2003; Saelens & Handy, 2008; Sallis, Cervero, Ascher, Henderson, Kraft, & Kerr, 2006; Sallis, Frank, Saelens, & Kraft, 2004). The slope of the terrain (Cervero & Duncan, 2003; Troped et al., 2001) and climate (Eves & Masters, 2006; Eves et al., 2008a) are natural barriers to physical activity whereas built environments restricted to homes are a manufactured barrier (Saelens & Handy, 2008; Sallis et al., 2004, 2006). Social and physical environments also facilitate physical activity. Supportive social partners are associated with walking (Giles-Corti & Donovan, 2003) and role models provided by other stair users have been linked to increased stair use, primarily for stair descent (Adams et al., 2006) and more specifically to stair climbing (Webb, Eves & Smith, 2010). A logical problem with the latter data should be noted; role models were more abundant on the escalators than on the stairs. For the built environment, proximity to utilitarian destinations and mixed land usage has been consistently associated with walking (McCormack, Giles-Corti & Bulsara, 2008; Saelens & Handy, 2008). Similarly, stair usage is related to the linkage of the stairs to key points of reference within the building, their visibility and the percentage of the building that they occupy (Nicoll, 2007). Despite the growing evidence base for ecological models for the outdoor environment, few studies have addressed the environment within workplaces. This paper investigates the contribution of social and physical environmental factors to stair usage in a worksite.

It is important to realize that choice of stairs, elevators and escalators occurs as part of a journey, with the different methods of ascent as barriers to be overcome on the way to the destination (Eves, 2008; 2010; Eves & Webb, 2006). Self-reports and observational data reveal journey time is an important consideration in public access settings (Adams et al., 2006; Eves, Lewis & Griffin, 2008b; Kerr, Eves & Carroll, 2001b) and worksites (Kerr et al., 2001a; Nicoll & Zimring, 2009). In public access settings, choice of the escalator may entail a small temporal delay to the journey if it is busy. Indeed, the almost ubiquitous effects of pedestrian traffic volume for public access staircases reflect increases in stair climbing as pedestrian traffic increases (e.g. Eves et al., 2008b; Eves, Olander, Nicoll, Puig-Ribera, & Griffin, 2009; Kerr et al., 2001b; Olander, Eves & Puig-Ribera, 2008; Webb & Eves, 2007); some travellers avoid delay by opting for the stairs when the escalator is busy. Nonetheless, the extent of the delay will be apparent to the traveller during the approach. Waiting for an elevator in a worksite, however, may entail an indeterminate delay to the journey. Hence, uncertainty about the effects of elevator availability on journey time may act as a barrier and influence choice between the alternatives of stairs and elevators.

Concerning factors that could influence elevator availability in a worksite, there is scant available information. Nicoll & Zimring (2009) recently reported on the effects of elevators that only stopped on every third floor, and hence were less available, coupled with an immediately available stair alternative. This set-up was associated with 33 times the stair usage of a complex where the elevator was coupled with a stairwell that required key-card access. Thus, reduced availability of a mechanized option, reflected in the number of elevators at any choice point, acts as a barrier to choice of the elevator and will make use of the stairs more likely. In the current study, we used a natural experiment to test the effect of the number of elevators by contrasting days when all elevators were in action with those on which one elevator was out of order. During the baseline period of a larger study (Eves, Olander, Webb, Griffin, & Chambers, 2010; Olander & Eves, 2010), one of the bank of elevators was intermittently out of order. It was predicted that both stair ascent and descent would be increased when one elevator was out of order and hence unavailable.

Concerning the social environment, no previous studies have assessed pedestrian movement within buildings. Nonetheless, the number of people in the building at any point in time, i.e. building occupancy, may affect elevator usage throughout the building; the more journeys required of the elevator, then the less likely it is to be available at a particular point-of-choice. As a result, increases in building occupancy would act as a barrier to elevator choice and increase the number of individuals choosing the stairs as a faster alternative. Hence, we hypothesized that increased building occupancy would be associated with increased stair usage. Additionally, building occupancy, and the demands on the elevators, may be linked with time of day. As employees arrive for work in the morning, building occupancy will increase, with a further increase reflecting any visitors arriving for meetings. Around lunchtime some fluctuation can be expected as some employees leave the building temporarily for lunch or an errand. Late in the day, building occupancy is likely to decrease as employees leave their workplace. Consequently, elevator availability may be related to time of day. The majority of employees will travel up the building in the morning and travel down in the afternoon, making the elevator less available in the morning on the ground floor compared to the afternoon. Hence, we hypothesised that increased time of day would be associated with reduced stair usage.

In addition to the above effects of pedestrian movement within the building, momentary pedestrian traffic at the choice point may influence stair and elevator choices. While pedestrian traffic volume has consistently been associated with greater stair climbing in public access settings (Eves et al., 2008b, 2009; Kerr et al., 2001b; Olander et al., 2008; Webb & Eves, 2007), the opposite effect has been reported in one previous worksite study though it was not replicated in a follow-up (see Kerr et al., 2001a). In a worksite, an employee arriving at the elevator may find a colleague already waiting for a summoned elevator. As a result, the waiting time for the elevator is likely to be reduced compared to if it had not been summoned and the arriving employee may take advantage of this. Indeed, the role model provided by a stranger waiting for the elevator may bias any arriving employee to choose the same option (Adams et al., 2006; Webb et al., 2010). Social interaction with any waiting colleagues could also reduce the likelihood of stair usage; observations of a public access setting reveal social groups, i.e. those talking or interacting, are less likely to take the stairs than individual travelers (Adams et al., 2006). Similarly, when two or more employees arrive at the elevator together, an individual’s choice may be influenced by any accompanying colleague who is unwilling or unable to take the stairs. The net outcome of these effects of momentary traffic would be to reduce the number of individuals choosing the stairs. Therefore, we predicted that increases in momentary pedestrian traffic would be associated with reduced stair use.

In summary, this study assessed the direction and magnitude of the effects of contextual factors that might influence stair use in a worksite for the first time. The primary aim was to model the contribution of factors related to elevator availability on stair and elevator usage at the ground floor. Both stair ascent and descent were measured at the ground floor with automated counters that tallied the number of employees using the stairs and elevators every minute. Whilst many studies in worksites have combined stair ascent and descent in their analyses (see Eves & Webb, 2006), the direction of travel was separated in the current study. Stair ascent uses two-three times the energy of stair descent, a fact that may explain the consistently higher rates of stair descent than ascent in buildings (e.g. Boutelle et al., 2001; Eves et al., 2006; Kerr et al., 2001a). Importantly, increased stair climbing offers a greater public health dividend than stair descent and hence is the preferred target (Eves et al., 2006; Eves & Webb, 2006). To assess building occupancy, we kept a running tally of individuals entering the building minus those leaving it, using the same automated counters to provide a continuous measure of the number of individuals in the building at any point in time. Time of day was operationalized as the cumulative minutes from the start of monitoring such that higher numbers occurred later in the day. While pedestrian traffic volume has been measured previously as the total number of pedestrians in successive 30 minute periods (Kerr et al., 2001a, 2001b) or the number leaving each train (Eves et al., 2009; Olander et al., 2008), the minute-by-minute measures here provide a better index of momentary pedestrian traffic at the point-of-choice. In summary, it was predicted that a reduced number of elevators and increased building occupancy would be associated with increased stair use. In contrast, we hypothesized that increasing pedestrian traffic and time of day would be associated with reduced stair use.

A secondary aim was to directly assess the relationship between elevator waiting time at the ground floor, building occupancy and time of day. In a follow-up study, we measured waiting time from the moment the elevator button was pressed until an elevator door opened. Waiting time was regressed against building occupancy and time of day. We predicted effects consistent with those on stair usage; waiting times would be positively related to building occupancy and negatively related to time of day.

2. Material and methods

2.1 Participants and setting

This study took place in a 12-floor worksite where most employees (N= 803; 50.9% male) had desk-based work duties. The building had four elevators and one stairwell; two elevators were positioned on either side of the central stairwell. Signs with LEDs above the elevators indicated their location within the building.

2.2 Materials

Employees entering and exiting the ground floor elevators and stairwell were recorded by unobtrusive automatic counters. These counters used two infrared beams in the horizontal plane and purpose built circuitry to distinguish the order in which the beams were broken. Thus, entry could be distinguished from exit for both the elevators and the stairwell. The output of this circuitry was stored on data loggers (µlogger RVIP, Zeta-tec, England), one for entry and one for exit which counted the number of pulses occurring each minute. One set of counters monitored the stairwell and two sets of counters monitored the elevators, one set for each pair of elevators positioned either side of the stairwell. The correlation between direct observations and automatic counts.min^{-1} for employees entering and exiting the stairs were $r(249)= .943$ and $r(249) = .952$ respectively, with equivalent correlations, $r(321)= .932$ and $r(321)= .935$ for those entering and exiting the elevators (all $p <.001$). Follow-up assessments revealed excellent inter-observer reliability for the observations of behavioral choice (average kappa=0.98, range 0.97-1.00).

2.3 Procedure

Monitoring took place every weekday between 7am and 7pm, with 16 non-consecutive days of four elevators available and 8 non-consecutive days of three elevators available. These time periods were chosen as the majority of employees worked between these hours, though some individuals entered the building before 7am (mean = 43 individuals, range 30-61). In addition to separate counts of stair and elevator use per minute for ascent and descent, two further measures were computed. Momentary pedestrian traffic for ascent and descent was operationalised as all individuals moving in each direction, irrespective of the mode of transit. Preliminary inspection revealed that pedestrian traffic values higher than $20.\mathrm{min}^{-1}$ were outliers (0.4% of data) and these data points were excluded from analyses. Building occupancy, i.e. the total number of individuals in the building at any point in time, was calculated by subtracting the number of individuals exiting the building from the number who had entered within that minute and adding the result to those who were already in the building. Time of day was operationalized as cumulative minutes from the start of monitoring such that it ranged from 0 (7am) to 719 (6.59pm).

In the follow-up study, elevator waiting time was measured with a stop watch as the time from when the elevator button was first pressed until the time an elevator door opened. Measurements were made for 30 minute periods throughout one day, starting each hour to cover the period 7am to 6pm, resulting in 257 separate measures of time to wait for an elevator. These times were averaged over five minute periods to produce a mean elevator waiting time prior to analysis so that waiting times could be compared with mean building occupancy and cumulative minutes over the same five minute periods. The study was approved by the School of Sport and Exercise Sciences Safety and Ethics Subcommittee at the University of Birmingham.

2.4 Statistical Analyses

Logistic regression was used to analyze stair vs. elevator choice with the potential predictor variables of elevator availability, building occupancy, time of day and pedestrian traffic. Prior to analysis, building occupancy, time of day and pedestrian traffic were standardized to a maximum score of one by dividing each measure by the maximum value obtained. This standardization facilitated comparison of the odds ratios with those for binary variables. Elevator waiting times were subjected to a natural log transformation to improve the distribution and analyzed by multiple regression with building occupancy and time of day as predictor variables.

3. Results

Figure 1 depicts the mean percentage ascending and descending to and from the ground floor respectively at each hour throughout the day and the mean building occupancy within the same time periods throughout the study. The data are averaged over hourly intervals and plotted for the mid-point of each interval, e.g. 7.30 am. As can be seen, a consistent shape emerged for building occupancy, with an inverted-U shape reflecting an increase during the morning contrasted with a decrease during the afternoon. In addition, fluctuations around lunchtime were apparent. Inspection of the bar part of the figure reveals complimentary data; ascent predominated in the morning as the building filled whereas descent increased in the afternoon as the building emptied.

A total of 46,129 counts for ascent (67.9% of those when 4 elevators were available) and 44,109 counts for descent (67.7% of those when 4 elevators were available) were recorded. Figure 2 depicts mean percentage of individuals using the stairs for ascent and descent throughout the study. Similarly to building occupancy in figure 1, stair use peaked around lunchtime and then decreased in the afternoon. In addition, it appears that, overall, stair use decreased below the morning levels during the afternoon.

The omnibus logistic regression on stair use, controlling for building occupancy, time of day and pedestrian traffic, revealed a main effect of elevator availability (Odds Ratio (OR) =1.13, 95% Confidence Interval (CI)= 1.08-1.19, $p<.001$) and a significant interaction between elevator availability and direction of travel (OR=1.20, CI 1.12-1.27, $p<.001$). Consequently, ascent and descent were analyzed separately. Table 1 summarizes the results of these analyses.

More individuals climbed the stairs when only three elevators were available (26.2%) compared to when four elevators were available (23.7%). Similarly, use of the stairs for descent was more common when there were three elevators available (34.2%) than four (28.0%). As can be seen from table 1, the confidence intervals for the effects of elevator availability on ascent and descent do not overlap, reflecting a greater effect of availability on descent than ascent. This explains the interaction term in the omnibus analysis.

In addition to these effects of elevator availability, building occupancy was positively associated with stair usage for both ascent and descent as predicted, with equivalent ORs for each direction of travel. Finally, pedestrian traffic and time of day were negatively associated with stair usage. Increasing time of day was associated with greater reductions on stair usage for ascent than descent, reflected in the non-overlapping CIs of the respective ORs.

Regression analysis for the follow-up study measuring elevator waiting times (mean = 6.85 s, SD = 6.24) revealed effects consistent with the results in table 1. That is, the waiting times were of intermediate duration in the morning (7-10am; 6.74 s, SD=3.94), peaked in the early afternoon (11am-2pm; 9.89 s, SD=7.93) and then decreased to be at their lowest in the late afternoon (3-6pm; 3.36 s SD=4.24). Building occupancy and time of day significantly predicted elevator waiting time ($F(2,65)=19.27$; $p<.001$), accounting for 35.3% of its variance. A positive effect for building occupancy ($\beta=.501$, $p<.001$) contrasted with a negative effect for time of day ($\beta=-.521$, $p<.001$).

4. Discussion

In summary, this study revealed increased stair use when one elevator was out of order consistent with predictions. These effects of elevator availability were greater for descent than ascent. Minute-by-minute measurements provided novel insights into the effects of building occupancy, time of day and momentary pedestrian traffic on stair use within buildings. As predicted, building occupancy was positively associated with stair use in the main study and elevator waiting time in the follow-up study. Conversely, time of day was negatively associated with stair use and elevator waiting times, with greater effects of time of day for stair ascent than descent. Finally, momentary pedestrian traffic was associated with reduced stair use as expected.

4.1 Factors influencing elevator availability

The physical environment, i.e. number of working elevators, and the social one of building occupancy influenced stair use. Both these factors may reflect availability of the elevator acting as a barrier to its use. A reduction in the number of working elevators and increases in building occupancy would both be associated with increased demand for the elevators throughout the building. As a result, an elevator would be less likely to be available at the ground floor point-of-choice, resulting in longer waiting times. The follow-up study confirmed the positive effect of building occupancy on waiting times. As outlined in the introduction, time to complete the journey is an issue for pedestrians (e.g. Eves et al., 2008b; Kerr et al., 2001a, 2001b). Factors which increase waiting time for the elevator, and hence journey time, act as barriers to elevator use. The resultant increase in the alternative option, namely the stairs, is consistent with effects of barriers to elevator use provided by structural aspects of the building (Nicoll & Zimring, 2009) or slowing of door closing time (van Houten, Nau & Merrigan, 1981). Demands on the elevators will affect the speed at which they travel between floors, and hence their availability at the choice point. Thus, increases in building occupancy will increase the delay to the journey associated with waiting for the elevator. Further, any information provided to a traveler of the elevator's location within the building by a display above the door will provide information about this delay and should influence the choice of both alternatives; employees report that they choose the faster alternative in workplaces (Kerr et al., 2001a).

The overall negative effects of time of day on stair use may, in part, also reflect availability of the elevator. Ascent into the building by both stairs and elevators increased during the morning and decreased in the afternoon (see figure 1). An ascending elevator that is moving away from the point-of-choice at the ground floor is likely to entail a greater delay for arriving travelers than one descending. Once again, information about the direction of travel, provided above the elevator door, could inform the choice of any traveler. Further, the greater effects of time of day for ascent than descent may reflect diurnal variations in pedestrian movement within the building. As people leave the building in the afternoon, many would use the elevator and hence its availability at the ground floor point-of-choice would be increased. As a result, choice of the elevator for ascent would be facilitated. Consistent with this, the follow-up study of waiting times revealed negative effects of time of day; waiting times were shorter as the day progressed. The decrease in stair use for descent to the ground floor may reflect travelers arriving at a point-of-choice above the ground floor and finding an elevator on its way down through the building. Once again, information from signs above the elevators could amplify this effect.

4.2 Effects of pedestrian traffic in buildings

Concerning the effects of the immediate social environment, as opposed to building occupancy, high momentary pedestrian traffic decreased use of the stairs for both ascent and descent. As outlined in the introduction, a colleague who has summoned the elevator, social interaction with that colleague or the role model provided by someone waiting could reduce use of the stairs. Additionally, groups traveling together (Adams et al., 2006) or any constraints imposed by the least mobile within the group could lead an individual traveler to take the elevator. While this finding replicates one previous workplace study for stair ascent (Kerr et al., 2001a), the same study reported no effects of traffic on stair descent. This discrepancy may reflect the restricted monitoring of Kerr et al. (2001a); stair and elevator use was only measured between 8-10am and 12-2pm when overall more individuals ascend than descend the building, irrespective of the method chosen for the journey (Eves et al., 2006; see also figure 1). The current study, however, measured stair/elevator descent throughout the day, including late afternoon when levels of descent were at their highest. From a broader perspective, minute-by-minute measurements of pedestrian traffic in buildings reveal opposite effects of traffic to those reported in public access settings (Eves et al., 2008b; Eves, et al., 2009; Kerr et al., 2001b; Olander et al., 2008; Webb & Eves, 2007). As this negative effect of traffic on stair use has been reported in two different buildings, it is not an effect specific to the building employed for this study (see also Eves, Webb, Griffin & Chambers, 2010). Consequently, encouraging individuals to act as role models who climb stairs rather than ride elevators may be a fruitful approach to increase the behavior of stair climbing (c.f. Andersen, Bauman, Franckowiak, Reilley & Marshall, 2008).

4.3 Implications for intervention success

This is the first study to use minute-by-minute measurements to quantify the effects of building occupancy, time of day and pedestrian traffic on stair use. It is informative to contrast the magnitude of these contextual, environmental effects with intra-personal factors associated with a desire to improve health and be more physically active. Point-of-choice interventions in worksites target these intra-personal factors, with increased stair climbing the preferred outcome given its greater physiological intensity (see Eves & Webb, 2006). The three published studies that successfully increased stair climbing promoted health and fitness (intervention OR = 1.05, Marshall et al., 2002), cardiovascular health (OR = 1.19, Eves et al., 2006) and calorific expenditure (OR=1.20, Olander and Eves, in press). The sample size weighted mean of these studies is a modest OR of 1.08. Three studies report effects specific to stair descent (OR=1.15, Eves et al., 2006; OR=1.21 and 1.31, Kerr et al., 2001a), with a similar moderate sample size weighted mean OR of 1.18. In contrast, the effects of contextual, environmental variables were considerably larger in this study.

Odds ratios above unity simplify comparisons between these environmental variables and the aggregated effects of interventions in previous studies. A reciprocal transformation of the ORs below unity in table 1, i.e. pedestrian traffic and time of day, is equivalent to reverse coding of the variables in these analyses. This transformation reveals that the effects of pedestrian traffic (OR=2.17) and time of day (OR=1.75), in keeping with the effects of building occupancy (OR=1.90) were an order of magnitude greater than the modest mean effect of interventions on stair climbing (OR=1.08). Similarly for descent, effects of pedestrian traffic (OR=2.19) and building occupancy (OR=1.94) were considerably larger than the mean effects of interventions (OR=1.18), though time of day was of comparable magnitude (OR=1.11). These comparisons reveal a key fact about stair climbing in workplaces. Contextual, environmental factors that are independent of the intervention have much greater effects on stair climbing than found with interventions targeting intra-personal factors. Failure to control for these variables in the design and subsequent analysis may restrict the ability to demonstrate effects for any intervention. Thus, the difficulty in replicating the successful stair climbing interventions on public access staircases in workplaces may simply reflect failure to partial out the influence of contextual variables.

From a broader perspective, the data on elevator availability have obvious implications for future building design; the fewer elevators in a building, the more likely that individuals will make physically active choices to move within that building. Further, the hypothesized effects of waiting time may be helpful. Reconfiguring the elevators in existing buildings such that they travel more slowly is likely to increase stair use just as slowing door closing increased stair use in an earlier study (van Houten et al., 1981). If possible, the more radical reconfiguring of multiple elevators so that some do not stop at every floor, i.e. skip-stop elevators, would have a similar effect (Nicoll & Zimring, 2009). Collectively, these findings indicate that journey time affects individuals' stair choice, an effect that might be harnessed to encourage individuals to make the healthy choice of using the stairs. Nonetheless, the greater effects of reduced elevator availability on descent than ascent suggest that presented with skip-stop elevators, some individuals may choose to ascend above their destination and walk down. This would be consistent with the greater physiological effort required for ascent and the lower rates of stair climbing than descent found here and in other studies in buildings (e.g. Boutelle et al., 2001; Eves et al., 2006; Kerr et al., 2001a).

Whilst the effects of elevator availability were greater for descent than ascent, the overall increase in stair use could be associated with health benefits. For example, past research has reported that by ascending and descending one flight of stairs an additional 15 times per day for 12 weeks, employees aerobic capacity increased, and their waist circumference, weight and fat mass decreased (Meyer et al, 2010). In addition, 110 climbed floors (i.e. walking to the top of the building twice a day, five days a week) corresponds to approximately 28 minutes of weekly vigorous physical activity (Meyer, Kayser & Mach, 2009), i.e. contributing about a third of the 75 weekly minutes of vigorous-intensity physical activity that is currently recommended to Americans (U.S. Department of Health and Human Services, 2008).

4.4 Limitations

While automatic counters allowed minute-by-minute measurements, they monitored bodies not individuals, and consequently no demographic or other individual characteristics that may influence stair use such as weight status, presence of bags or type of clothing, were available. In public access settings, men, the young and those without large bags consistently take the stairs more than their comparison groups (e.g. Eves et al., 2008; 2009; Webb and Eves, 2005, 2007). The evidence in worksites, however, is mixed. Men climb the stairs more than women in three studies (Study 2, Eves et al., 2006; Kerr et al., 2001a; Olander and Eves, in press), with one study reporting the opposite (Study 1, Kerr et al., 2001a). For bags, Eves et al., (2006) and Kerr et al., (2001a; study 2) reported effects on ascent and descent whereas Kerr et al., (2001a; study 1) report no effects. Automated counters preclude any resolution to these discrepancies and studies with direct observation are required. Additionally, direct auditing could answer questions about other characteristics that have been reported to influence choice such as weight status (e.g. Eves et al., 2006) or wearing sport shoes (e.g. Adams et al., 2006). In particular, information about the clustering of individuals would facilitate interpretation of the negative effects of pedestrian traffic on stair use. Set against this limitation, the fine detail possible with automatic counters provided unique data about contextual factors with large magnitude effects on the behaviour.

This study only measured stair and elevator use at the ground floor point-of-choice. As height of the climb, and hence height of the building, is negatively associated with stair climbing (Eves & Webb, 2006; Olander & Eves, in press), the destination of any traveler is likely to influence the choice. An individual whose destination or start point is the sixth floor would require approximately six times more time and effort to use the stairs than an individual journeying between the first floor and the ground. Hence, measurements at the ground floor cannot assess the potential effects of journey extent and monitoring of individuals would be required to disentangle the effects of waiting time and associated effort.

Finally, logistic regression assumes independence of observations whereas it is likely that the same individuals would be observed some of the time in a worksite. It should be noted, however, that elevator availability and momentary pedestrian traffic may differ between separate choices made by the same individual and, hence, the resultant choices would be partially independent. Further, logistic regression appears the best approach to analysing the granularity inherent in binary choices at the minute-by-minute level.

5. Conclusions

To date, the evidence for effectiveness of stair climbing campaigns in worksites is equivocal (Eves, 2008, 2010; Eves & Webb, 2006). Minute-by-minute measurements of the current study revealed effects of building occupancy, time of day and pedestrian traffic on stair/elevator choice. The magnitude of the effect of these variables is greater than the typical intervention effects in worksites. Consequently, researchers should control for these factors when assessing workplace stair climbing interventions.

References

Adams, M. A., Hovell, M. F., Irvin, V., Sallis, J. F., Coleman, K. J. & Liles, S. (2006). Promoting stair use by modeling: An experimental application of the behavioral ecological model. *American Journal of Health Promotion, 21,* 101-109.

Andersen, R. E., Bauman, A. E., Franckowiak, S. C., Reilley, S. M. & Marshall, A. L. (2008). Prompting health professionals to be activity role models—motivating stair use at the 2001 ACSM scientific meeting. *Journal of Physical Activity and Health, 5,* 607-618.

Boreham, C. A. G., Kennedy, R. A., Murphy, M. H., Tully, M., Wallace, W. F. M., Young, I. (2005). Training effects of short bouts of stair climbing on cardiorespiratory fitness, blood lipids, and homocysteine in sedentary young women. *British Journal of Sports Medicine, 39,* 590-593. doi:10.1136/bjsm.2002.001131

Boutelle, K. N., Jeffery, R. W., Murray D. M. & Schmitz, M. K. (2001). Using signs, artwork, and music to promote stair use in a public building. *American Journal of Public Health, 91*, 2004-6.

Cervero, R. & Duncan, M. (2003). Walking, bicycling, and urban landscapes: Evidence from the San Francisco Bay area. *American Journal of Public Health*, *93,* 1478-1483.

Department of Health. (2005). *Choosing activity: a physical activity action plan.* Department of Health Publications; London.

Eves, F. F. (2008). All choices are not equal; Effects of context on point-of-choice prompts for stair climbing. *Obesity Reviews, 9,* 83-84. doi: 10.1111/j.1467-789X.2007.00372.x

Eves, F. F. (2010). Point-of-decision prompts to increase stair use. *American Journal of Preventive Medicine, 38,* 573-574. doi:10.1016/j.amepre.2010.02.004

Eves, F. F., Lewis, A. L., Griffin, C. (2008b). Modelling effects of stair width on rates of stair climbing in a train station. *Preventive Medicine, 47,* 270-272. doi: 10.1016/j.ypmed.2007.12.008

Eves, F. F., & Masters, R. S. W. (2006). An uphill struggle: Effects of a point-of-choice stair climbing intervention in a non-English speaking population. *International Journal of Epidemiology, 35,* 1286-1290. doi: 10.1093/ije/dyl141

Eves, F.F., Masters**,** R.S.W., McManus, A., Leung, M., Wong, P., & White, M.J. (2008a). Contextual barriers to lifestyle physical activity interventions in Hong Kong. *Medicine and Science in Sports and Exercise, 40,* 965-971. doi: 10.1249/MSS.0b013e3181659c68

Eves, F. F., Olander, E. K., Nicoll, G., Puig-Ribera, A. & Griffin, C. (2009). Increasing stair climbing in a train station; Effects of contextual variables and visibility. *Journal of Environmental Psychology, 29,* 300-303. doi: 10.1016/j.jenvp.2008.10.002

Eves, F. F., Olander, E. K., Webb, O. J., Griffin, C. & Chambers, J. (2010). *Likening the stairs in buildings to climbing a mountain; Self-reports and objective measures of effectiveness.* Manuscript submitted for publication.

Eves, FF., Webb, OJ., Griffin, C. & Chambers, J. (2010). *A multi-component stair climbing intervention targeting calorific expenditure for worksites; Effects on behavior, attitude and intention.* Manuscript submitted for publication.

Eves, F. F. & Webb, O. J. (2006). Worksite interventions to increase stair climbing;

Reasons for caution. *Preventive Medicine, 43,* 4-7. doi: 10.1016/j.ypmed.2006.03.011

Eves, F. F., Webb, O. J. and Mutrie, N. (2006). A workplace intervention to promote stair climbing: Greater effects in the overweight. *Obesity, 14,* 2210-2216. doi: 10.1038/oby.2006.259

Frank, L. D., Saelens, B., Powell, K. E., & Chapman, J. (2007). Stepping towards causation: Do built environments or individual preferences explain walking, driving, and obesity? *Social Science and Medicine, 65,* 1898–1914. doi: 10.1016/j.socscimed.2007.05.053

Giles-Corti, B., & Donovan, R. J. (2003). Increasing walking: The relative influence of individual, social environmental and physical environmental factors. *American Journal of Public Health, 93,* 1583-1589.

Kennedy, R. A., Boreham, C. A., Murphy, M. H., Young, I. S. & Mutrie, N. (2007). Evaluating the effects of a low volume stairclimbing programme on measures of health-related fitness in sedentary office workers. *Journal of Sports Science & Medicine, 6,* 448-454.

Kerr, J., Eves, F. & Carroll, D. (2001a). Can posters prompt stair use in a worksite environment? *Journal of Occupational Health, 43,* 205-207.

Kerr, J., Eves, F. & Carroll, D. (2001b). Getting more people on the stairs: The impact of a new message format. *Journal of Health Psychology, 6,* 495-500. doi: 10.1177/135910530100600503

Kerr, N. A., Yore, M. M., Ham, S. A. & Dietz, W. H. (2004). Increasing stair use in a worksite through environmental changes. *American Journal of Health Promotion, 18,* 312-315.

Marshall, A. L., Bauman, A. E., Patch, C., Wilson J. & Chen, J. (2002). Can motivational signs prompt increases in incidental physical activity in an Australian health-care facility? *Health Education Research*, *17,* 743-749. doi: 10.1093/her/17.6.743

McCormack, G. R., Giles-Corti, B., & Bulsara, M. (2008). The relationship between destination proximity, destination mix and physical activity behaviors. *Preventive Medicine, 46,* 33-40. doi: 10.1016/j.ypmed.2007.01.013

Meyer, P., Kayser, B., Kossovsky, M. P., Sigaud, P., Carballo, D., Keller, P.-F., … Mach, F. (2010). Stairs instead of elevators at workplace: Cardioprotective effects of a pragmatic intervention. *European Journal of Cardiovascular Prevention & Rehabilitation, 17*, 569-575. doi: 10.1097/HJR.0b013e328338a4dd

Meyer, P., Kayser, B., & Mach, F. (2009). Stair use for cardiovascular disease prevention. *European Journal of Cardiovascular Prevention & Rehabilitation, 16* (Suppl 2), S17-18. doi: 10.1097/01.hjr.0000359230.73270.2e

Nicoll, G. (2007). Spatial measures associated with stair use. *American Journal of Health Promotion, 21*, 346-352.

Nicoll, G. & Zimring, C. (2009). Effect of innovative building design on physical activity. *Journal of Public Health Policy, 30,* S111-S123. doi: 10.1057/jphp.2008.55

Olander, E. K. & Eves, F. F. (in press). Effectiveness and cost of two stair climbing interventions – Less is more. *American Journal of Health Promotion.*

Olander, E. K. & Eves, F. F. (2010). *Getting more employees on the stairs: the impact of a calorific expenditure message.* Manuscript submitted for publication.

Olander, E. K., Eves, F. F. & Puig-Ribera, A. (2008). Promoting stair climbing: Stairriser banners are better than posters... sometimes. *Preventive Medicine*, *46,* 308-310. doi:10.1016/j.ypmed.2007.11.009

Saelens, B. E. & Handy, S. L. (2008). Built environment correlates of walking: A review. *Medicine & Science in Sports & Exercise,40,*S550-S566. doi: 10.1249/MSS.0b013e31817c67a4

Sallis, J.F., Cervero, R.B., Ascher, W., Henderson, K.A., Kraft, M.K., and Kerr, J. (2006). An ecological approach to creating more physically active communities. *Annual Review of Public Health, 27,* 297-322.

Sallis, J.F., Frank L.D., Saelens, B.E., & Kraft, M.K. (2004). Active transportation and physical activity: Opportunities for collaboration on transportation and public health. *Transportation Research Part AI, 38,* 249-268. doi:10.1016/j.tra.2003.11.003

Soler R. E., Leeks, K. D., Buchanan, L. R., Brownson, R. C., Heath, G. W. & Hopkins, D. H. (2010). Point-of-decision prompts to increase stair use; A systematic review update. *American Journal of Preventive Medicine, 38,* S292–S300. doi: 10.1016/j.amepre.2009.10.028

Troped, P. J., Saunders, R. P., Pate, R. R., Reininger, B., Ureda, J. R., & Thompson, S. J. (2001). Associations between self-reported and objective physical environmental factors and use of a community Rail-trail. *Preventive Medicine*, *32,* 191-200. doi: 10.1006/pmed.2000.0788

Van Houten, R., Nau, P. A. & Merrigan, M. (1981). Reducing elevator energy use: A comparison of posted feedback and reduced elevator convenience. *Journal of Applied Behavior Analysis, 14*, 377-387. doi: 10.1901/jaba.1981.14-377

U.S. Department of Health and Human Services. (2008). *2008 Physical activity guidelines for Americans.* Department of Health and Human Services;

Washington D. C.

Webb, O.J., & Eves, F.F. (2005). Promoting stair climbing: Single vs. multiple messages. *American Journal of Public Health, 95,* 1543-1544. doi: 10.2105/AJPH.2004.046235.

Webb, O.J., & Eves, F.F. (2007). Promoting stair climbing: Intervention effects generalize to a subsequent stair ascent. *American Journal of Health Promotion, 22,* 114-119

Webb, O.J., Eves, F.F. & Smith, L. (2010). Investigating behavioural mimicry in the context of stair/escalator choice. *British Journal of Health Psychology.* Advance online publication. doi: 10.1348/135910710X510395

Table 1. Odds ratios (OR) and 95% confidence intervals (CIs) of elevator availability, building occupancy, pedestrian traffic and time of day for stair ascent and descent.

	Ascent (N=46,129)		Descent (N=44,109)	
Variable	OR	CIs	OR	CIs
3>4 elevator availability	1.13***	1.08-1.18	1.36***	1.30-1.41
Building occupancy	1.90***	1.69-2.13	1.94***	1.73-2.17
Pedestrian traffic	0.46***	0.40-0.53	0.46***	0.40-0.52
Time of day	0.57***	0.52-0.64	0.90*	0.82-0.98

*p<.05; ***p<.001

Figure 1. Mean percentage ascending (N=46,129) and descending (N=44,109) from the ground floor and mean building occupancy per hour throughout the study.

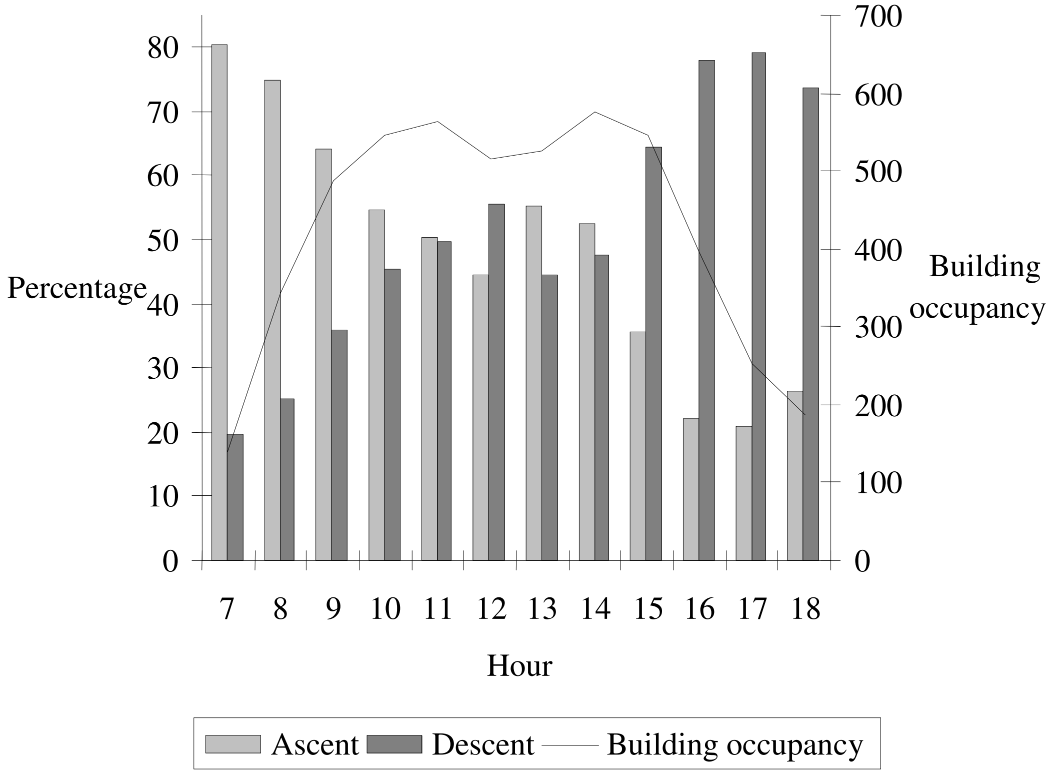

Figure 2. Mean percentage of employees using the stairs for ascent (N=46,129) and descent (N=44,109) per hour throughout the study.