Bone Strength of Students in the UAE

Sub-title: An investigation into lifestyle, bone quality and bone density of students in the United Arab Emirates (UAE)

by Penelope Jane Bell

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ABSTRACT

Bone strength in this Arab country, as in the rest of the world, is assessed by measuring bone quality with Quantitative Ultrasound (QUS) and bone quantity with Dual Energy Xray Absorptiometry (DXA), and comparing the results to reference ranges. However, in the absence of accepted Arab reference ranges for either technique, Caucasian reference ranges are used. This study aimed to discover the average male and female values for bone strength in young adults in order to determine the suitability of employing the Caucasian reference range for clinical diagnosis of bone strength. Lifestyle factors known to influence bone strength were also investigated. The study design was a cross sectional survey of student volunteers, aged 18 to 25. Bone strength was assessed for all volunteers with QUS using two techniques and, for a sub-set of students, with DXA. Lifestyle factors including calcium intake and physical exercise were examined. The study took place during the Spring semester of 2005 and included healthy Arabs.

The number of volunteers was 337 from which, due to exclusion criteria, 41 were removed leaving a total of 296; 120 males and 176 females. Although the nationalities of the students varied, almost all of them had lived most of their lives in the United Arab Emirates (UAE). Ultrasound stiffness index of the left heel showed that Arab males measured the same as Caucasian females. No male Caucasian reference was available. Arab females however, had a mean stiffness index significantly lower than Caucasian females by 6 percent, $p < 0.001$. Phalangeal QUS was found to be unreliable as it did not correlate with heel data or hip DXA. Average hip bone density for 31 males matched Caucasian male reference data, mean 1.037 g/cm^2. Bone density of 38 females scanned was 11 percent lower than the female Caucasian reference, $p < 0.001$. This study suggests that as the difference in bone strength between Arabs and Caucasians is only seen in females it may not be an ethnic difference, as previously assumed, but instead may be due to the difference in lifestyle.

Abstract

Analysis showed effects on bone strength from several risk factors. Calcium intakes were the same for both groups and were approximately half of the recommended daily amount. Odds ratios for a low DXA result were 1.264 (CI 1.038-1.496) with low calcium intake. Increased numbers of fractures correlated negatively with increased bone strength for QUS and DXA. Low body mass index (BMI) gave an odds ratio for low QUS of 1.6 and low DXA of 3.1 (CI 1.341-6.947). Most males were physically active but the females were inactive, performing 80 % less exercise than their male counterparts. However, correlation of exercise to both QUS and DXA bone strength was present for females. Further research is recommended with emphasis on including larger numbers of physically active females.

1. INTRODUCTION

1.1 Aims and Objectives

1.1.1 General

At the core of the body are bones, providing a framework for muscles and organs and facilitating mobility. An immobile person rapidly suffers health impairment which could ultimately lead to death. Strong bones are vital for maintaining good health. Broken bones occur as a result of injury or trauma, however, the same degree of trauma may fracture a bone in one person and not another. This is because of differences in the characteristics of bone tissue, affecting its strength. Disease may be the cause of such differences but in healthy people the two factors involved in determining bone characteristics are lifestyle and genetic make-up. This thesis is concerned with looking at these factors in the population of a country which has as yet been only minimally studied, the United Arab Emirates (UAE).

Bone strength can be estimated by using machines to measure characteristics such as quality and density. The genetic variation in bone seen between ethnic groups, although it cannot be altered, should be understood and accounted for when measurements are taken from machines to look for bone weakness. This is done by having a normal reference range of values loaded into the machine's computer system for each ethnic group, to which an individual measurement can be compared. An analogy for this can be seen in pulse rates for adults and children. The pulse rate of a normal child, if compared to the reference range for adults, would be considered extremely high.

In the UAE the population is made up predominantly of Arabs. The equipment used for measuring bone density and quality is the same as that used elsewhere in the world. Reference data, which have to be collected over considerable time from large studies, are not available for the UAE population on these machines. They usually contain only Caucasian, African, Asian or Hispanic references. Clinicians in the UAE use the Caucasian or European data as a reference because Arabs are thought to be genetically closest to Caucasian in ethnicity (Suhaili, 2004, Desouki, 2005). The word Caucasian

was originally introduced by 19th century anthropologists categorizing human races and referred to white skinned people from Europe, Western Asia, and parts of India and North Africa. The use of the word has evolved today to mean white or of European origin (Soanes, 2004). The words European and Caucasian are used interchangeably in this thesis.

Investigating the normal range of bone quality and density values for young, healthy Arab students in the UAE is a major target for this thesis in order to discover how similar or different they are compared to currently available Caucasian references. Treatment is prescribed to patients based on the diagnosis of low bone strength obtained from comparison of Arab bone measurements to standard normal Caucasian values, this may be either incorrectly identifying subjects as having weak bones when they do not, or conversely not detecting weakness though it is present.

The lifestyle chosen by each person has an enormous impact upon general health, including bone density and quality. The fact that there are known guidelines which indicate how to ensure healthy bones leads to the next important part of this thesis which is to try to discover whether optimum lifestyles are being pursued by UAE Arab students, or whether bad habits are causing the students to have less than healthy bones. Two very important factors for obtaining and maintaining healthy bones are adequate weekly physical exercise and adequate dietary intake of calcium. The full set of lifestyle factors will be detailed later in this work. Personal choice plays a large role in behavior and it would be feasible to launch a publicity campaign within educational institutions aimed at improving lifestyle, thus improving bone health. The environment where the students spend the majority of their time, for an average of five years, could also be modified to support healthier habits. One such example is the provision of a dedicated sports facility in the University of Sharjah for the female students on campus who previously had to go off site, which in this cultural situation is not straightforward but requires exit passes. During the period of time that this research has been underway, this sports complex has been completed. The amount of use it will get from the female students remains unknown but would be a good area for further study.

If an accident occurs to a person with completely healthy bones and enough force is applied, any bone could be broken. However, when the force of the injury is minimal

some people will still fracture. Osteoporosis is the name of the condition in which any injury, even the mildest, is very likely to result in a fracture. In these cases the bones are already in a weakened state but since they are not visible this cannot be outwardly detected. Generally, the lower the bone density and quality, the higher the likelihood of sustaining a fracture. Several methods exist which quantify characteristics of bone such as its density and quality. Clinicians may also estimate bone health by checking for the presence of lifestyle risks such as inadequate calcium intake or lack of physical exercise. In previous years osteoporosis could only be diagnosed once the symptoms had occurred, i.e. the patient suffered a bone fracture, height loss or back pain. Now osteoporosis can be detected through bone mass measurements. It is also possible to predict which patients might suffer from osteoporosis in the future. There are many treatment options and advice on lifestyle that can be offered in order to reduce the impact of this serious disease (Asch, 1998).

This research into bone strength of UAE students was undertaken from the University of Sharjah (UOS). Sharjah is one of seven Emirates in the UAE which are: Abu Dhabi, Dubai, Sharjah, Fujairah, Umm Al Quwain, Ajman and Ras Al Khaimah. The UAE is a Gulf Country and is situated in the Middle East. The UAE was founded in 1971. It is an Arab country whose religion is Islam (Matthew, 1999). Islam and the Muslim culture are interpreted by many as proscribing lifestyle behaviors which are relevant to increasing bone strength, in particular exposing any areas of skin to the sun. Skin exposure to sunlight enables the body to manufacture vitamin D, necessary for calcium absorption and strong bones. All Arabs domiciled in the UAE will have been exposed to a group of conditions concerning diet, exercise and mode of dress which are particular to this geographical location thus forming a cohort for study, even though they have different nationalities.

Methodological and ethical approval was given by the UOS for this study of lifestyle, bone quality and density to be performed on both female and male students. Methodological and ethical approval was also given by the Dubai Women's College (DWC), part of the UAE Government's Higher Colleges of Technology (HCT), for the same study thus providing a third group of students. Students at the UOS are predominantly Arabs but from a large group of different nations. DWC students are all UAE national female Arabs. It has been noted previously that bone density and quality

vary between ethnic groups but there is also a difference between males and females. Males have higher normal bone strength than women and hence any measurements must be compared to appropriate male or female reference curves. The participants in this study were therefore divided into three groups: 1/ UOS females of all Arab nationalities (expatriate and UAE nationals), 2/ UOS males of all Arab nationalities (expatriate and UAE nationals) and 3/ DWC females of UAE Arab nationals only. Two subject groups, for whom nothing is currently known, are UAE expatriate Arab females and all UAE Arab males living permanently in this country - groups 1/ and 2/ national or UAE Arab females, similar to group 3/, have been the subject of initial studies at another University in the UAE but the two previously mentioned groups, 1/ and 2/, will be investigated for the first time and baseline data produced.

Until recently the focus of concern for medical research into osteoporosis had been on post menopausal women, who are at the highest risk of developing the condition due to more rapid bone loss at this age than occurs in similar aged men. There has been a change in emphasis to consider young people and their development of peak bone mass (PBM), because by attaining the maximum possible PBM the incidence of osteoporosis can be reduced or delayed. PBM denotes the point in time when normal bone formation and bone loss are at equilibrium. Although bone turnover is continual throughout life, during childhood and adolescence bone formation exceeds bone loss resulting in a net gain. From the mid twenties onwards this is reversed and bone loss exceeds bone formation causing a continual loss of bone over the years. Any person could become osteoporotic should they live long enough and people generally are living much longer than they used to in developed countries such as the UAE.

This change in emphasis to focusing on research of children and adolescents was recorded in 1999 by the National Institute of Health (National Institute of Health, 1999). At the start of this research project in 2000, PBM was just emerging as an important issue. Lifestyle factors impact heavily upon attainment of peak bone mass and are habits which can be modified or controlled thus both optimizing bone strength and reducing the later incidence of osteoporosis.

Much research has been done internationally in the area of PBM, but bone characteristics differ for each ethnic group. A graph can be drawn to plot bone strength

over time, the gradual increase in bone strength leading to PBM followed by gradual bone loss, but for each ethnic group the curve is unique. Africans have stronger bones than Caucasians. Caucasians have stronger bones than Asians. Also there are differences in the age at which peak bone mass is achieved between areas of the skeleton (e.g. the hip, spine or phalanges) and, for the same bone, differences between ethnicities. For example, the bone density in the hip of a normal 20 year old African may be read from the reference curve as 1.1 grammes per centimeter squared (g/cm^2) whereas a normal Caucasian may only be expected to have a density of 1.0 g/cm^2. Another example of ethnic variation would be that peak bone mass may be reached in a Caucasian male hip at the age of 16, whereas it may not be reached until 18 years for an Asian male. (These examples do not reflect actual values but have been created to illustrate the point. For actual values the relevant curves should be consulted.) It is therefore vital to compare a single measurement to the correct graph in order to determine if the reading is low, normal or high. To the author's current knowledge, only minimal research has been carried out on the UAE population by a group of researchers at the Emirates University, Al Ain. At the time of writing, they have produced three papers all of which included only national UAE women (Saadi *et al*, 2001, 2003 and 2004).

There are a large number of Arab expatriates from surrounding countries permanently domiciled in the UAE who deserve consideration. Even more importantly, males have not been studied at all although male osteoporosis is an important medical concern. This research project will be unique in targeting these two previously overlooked groups, of Arab females and Arab males (national and expatriate), whilst adding to the findings already available for national females. The UAE is a country with few nationals, 800,000 or 20% of the population of 4 million. Further, there are twice as many males than females. It is vital that work begins in order to investigate bone and lifestyle factors for these groups.

1.1.2 Aims

Specifically, based on all the points mentioned, the aims and objectives of this research study are as follows:

1. Address the gap in knowledge regarding the normal bone strength of Arabs, national and expatriate, males and females, in the UAE.

2. Describe mean bone strength values for UAE students and compare to known normal values for other ethnic groups.

3. Discover the prevalence of low bone strength.

4. Highlight cases of low bone strength to students.

5. Investigate dietary factors and exercise levels, in order to determine whether they fulfill recommended criteria for the prevention of osteoporosis.

6. Compare the prevalence of osteoporosis risk factors between males and females.

7. Investigate the use of a new technique for bone assessment.

8. Aid in the dissemination of information regarding awareness of osteoporosis and its risk factors.

9. Discover whether there would be a need for further intervention in modifiable lifestyle factors which could be implemented through the educational setting.

1.1.3 Objectives

1. Collect a conveniance sample of male and female students from all Arabs studying at the UOS and female students from DWC in order to perform a cross-sectional study.

2. Perform quantitative ultrasound (QUS) scanning of both calcanei to measure bone quality.

3. Perform quantitative ultrasound (QUS) scanning of the phalanges of the non-

dominant hand to measure bone quality.

4. Perform dual energy X-ray absorptiometry (DXA) of the total hip to measure bone mineral density.

5. Perform magnetic resonance imaging (MRI) scanning of the calcaneum to pilot a new technique for bone assessment.

6. Investigate relationships between the bone measurement techniques.

7. Administer a lifestyle tool to gather information on all relevant osteoporosis risk factors.

8. Discover any correlations between risk factors and any of the bone strength measurements.

9. Inform all students of their bone strength measurement results.

10. Advise any students with low bone strength to follow-up with a visit to their own physician.

11. Disseminate statistically significant results to the interested parties and the wider osteoporosis research community through publication and presentation.

1.1.4 Hypotheses

This research will test the primary hypothesis that bone strength of the UAE Arab population is lower than the European reference range. Some evidence that this is true for females already exists, as mentioned earlier, but for males baseline data will be produced. The null hypothesis is that UAE Arabic bone strength is not different from the reference range for Europeans, which is currently in clinical use.

The secondary hypothesis to be tested is that one or more risk factors for low bone strength are present and that the bone strength of students with risk factors is different

to those without risk. The null hypothesis is that no risk factors for low bone density are present or if they are, the bone strength of students with risk factors is the same as those without.

Bone strength will be measured by one or more of three machines. Two of the machines are peripheral QUS devices, one for the calcaneum and one for the phalanges, to look at bone quality. The third piece of equipment to be used is DXA and this will measure bone density. Bone strength measurements will be the dependant factors in this study. A fourth bone examination will be carried out as a feasibility study for later use in another project, MRI scanning, on a limited number of students.

1.1.5 Risk Factors

Primary causes of low bone strength can be divided into categories of either modifiable or non-modifiable. Secondary causes of low bone mass include: endocrinopathies, drugs, malabsorption, marrow-based and neoplastic disorders, inherited disorders and osteomalacia according to the International Society for Clinical Densitometry (ISCD) (2003), these are listed more fully in Table 2.

The dependant values for bone strength could be modified by some independent factors, known as osteoporosis risk factors. Risk factors to be measured in this study, determined from current literature and international organizations around the world, are as follows:

1. Body Mass Index (BMI)
2. Exercise amount and level of intensity
3. Calcium intake
4. Smoking
5. Caffeine consumption
6. Carbonated drink consumption
7. Age at menarche, menstrual regularity
8. Sunlight exposure
9. Fractures

Each of these risk factors will be introduced and described in full detail later in this introductory chapter, but before that, the next section will describe osteoporosis from definition to treatment in order to explain the nature of the condition upon which this thesis is based.

1.2 Osteoporosis, the Disease

1.2.1 Definition

Osteoporosis literally means porous bone. The term osteoporosis has been clinically defined as a metabolic bone disease characterized by low bone mass and microarchitectural deterioration of bone tissue leading to enhanced bone fragility and a consequent increase in fracture risk (Anonymous, 1993). This definition was the preferred one until the National Institute of Health (NIH) introduced the following classification: a skeletal disorder characterized by compromised bone strength predisposing to an increased risk of fracture. Bone strength reflects the integration of two main features: bone density and quality (NIH, 2001). The main components of this thesis are referred to in this definition; bone density and quality.

Although measurements of these two parameters of quality and density are available, it is possible to diagnose osteoporosis in a person without any measurement. Clinically, it can be confirmed in the presence of a fracture caused by minimal trauma (e.g. a fall from standing height, or less) as described by the World Health Organisation (WHO) (2003).

As an alternative to the clinical diagnostic definition above, there is also a bone strength definition derived from measurements taken from a machine. However, the absolute value of bone strength as a measurement e.g. a density of 1.0 g/cm^2, cannot be used alone to diagnose osteoporosis. The concept has been introduced earlier in this work that each group of people have their own set of reference data for normal ranges of values and the absolute measurement obtained must be compared to this range. When the value is plotted on the normal reference range curve, another value known as the T-score can be read. T-scores are in units of standard deviation (SD) from the mean bone strength value for a young adult. The absolute number in g/cm^2, that one T-score

unit represents, differs from one curve to another because the standard deviation is a measure of the spread of all the measurements in that data set and will be different from curve to curve. The use of T-scores allows for a diagnosis of osteoporosis from bone strength measurement devices by assessing how far the reading is below that of a normal young adult or how much bone strength has been lost since youth. The most commonly used cut off point for diagnosing osteoporosis from a machine measuring bone strength is a T-score of below -2.5 SD. If a T-score reading is below -2.5 SD then the person is diagnosed as having osteoporosis (WHO, 1994).

Osteoporosis is a non-communicable disease (NCD). The World Health Organization (WHO) estimates that non-communicable diseases (NCDs), mental health disorders and injuries will soon contribute more than 70% of the global burden of disease (WHO, 2001). The WHO further state the following: 1/ that NCDs will sharply increase in mid to low income countries up to 2020, 2/ that increasing exposure to risk factors such as tobacco and increasing population age are causing an NCD epidemic, 3/ that global health research almost totally neglects NCDs and 4/ the prevalence and trends of risk factors associated with NCDs must be evaluated. The UAE has a good income from oil, trade and tourism but is certainly exposed to lifestyle risks such as tobacco and poor diet incurred by the rising consumption of fast food. Medical facilities and expertise continue to improve with the improving economy and population growth of the country, leading to increased population age. The longer a person lives, the more likely they are to suffer osteoporosis due to continual, natural bone loss. Little research has been done on osteoporosis and bone strength in the UAE, and further knowledge is needed in this region. This project aims to address both bone strength and the risk factors associated with it.

In the United Kingdom a steering committee has been formed with the title Bone and Joint Decade 2000-2010. One of the members was Anthony Woolf, then Chairman of the UK National Osteoporosis Society. In a bulletin for the WHO he stated that there has been a change in lifestyle resulting in less exercise and poorer diets, factors which increase the risk of osteoporosis (Woolf, 1999). The idea for this work partly resulted from observation of UAE students and the population in general and from noticing that exercise in young women is extremely uncommon and almost unfashionable. Perhaps due to the very high temperatures, up to 48 degrees in the summer with 100%

humidity, and the custom of covering the body from head to foot in long dresses and a black cloak, the lifestyle is sedate. Physical exercise is an important lifestyle factor which when not done causes low PBM and low bone strength. This project aimed to estimate the levels of exercise undertaken by the students, as one of the lifestyle factors being studied, and to investigate links between exercise levels and bone strength.

1.2.2 Pathophysiology

Bone is a hard, dense connective tissue. It forms the skeleton of the body and supports the weight of all other tissues and organs. It consists of a matrix of collagen or protein fibres impregnated with mineral salts. These salts are principally calcium phosphate and some calcium carbonate and are deposited in crystalline form (calcium hydroxyapatite). Small amounts of other minerals are also present which are magnesium hydroxide, fluoride and sulfate. Calcification or mineralization happens when the mineral salts are incorporated into the collagen matrix. They crystallize causing the structure to harden. Osteocytes or bone cells are embedded in this matrix for the purpose of obtaining nutrients from, and returning waste to, the blood. Bone is hard but it is also flexible. Flexibility is dependant on the collagen fibres which provide tensile strength; resistance to stretching. Bone tissue is not solid but is a three dimensional latticework of struts with spaces in between. In some of the spaces there is bone marrow and others are for blood vessels (Tortora, 2000).

Osteoblasts make collagen fibrils and osteoid which is the uncalcified base material of bone (Adler, 2000). In order that calcification can occur, alkaline phosphatase in high concentrations must be present in the osteoblasts. Osteoblasts are spindle shaped and no longer divide but, after calcification, become incorporated into the bone matrix. Osteoblast mitochondria contain a reservoir of intracellular calcium and also produce the alkaline phosphatase which is used when mineralization takes place under their control. Through continual contact with osteocytes these cells help transport calcium in and out of bone.

Osteoclasts are responsible for resorption of calcified bone. They are multinucleated

and have a brush type border which carries acid phosphatase. The cells have protein destroying enzymes which facilitate resorption (Adler, 2000).

There are two types of bone tissue. Cortical bone or compact bone forms the shell of bones. It is solid with blood vessels running through it in Volkmann's canals. Around the canals are rings of calcified matrix called lamellae with lacunae (small spaces). Approximately 80% of the skeleton is compact bone. Cancellous, spongy or trabecular bone accounts for the remaining 20% and is a porous network of fibres or trabeculae (columns of lamellae). These trabeculae are lined up along lines of stress and have the ability to realign if the direction of stress changes. This type of bone is lighter than compact bone, allowing it to be more easily pulled by a muscle. Red bone marrow is found in the spaces between trabeculae of spongy bone.

Bone cells are of four types: 1/ osteogenic cells are bone stem cells (which divide to become osteoblasts), 2/ osteoblasts form bone by making and secreting collagen, 3/ osteocytes are mature bone cells (osteoblasts become oesteocytes after they are trapped in the collagen matrix) and 4/ osteoclasts are large cells producing acids to digest bone as part of bone remodeling.

The process of forming and resorbing bone goes on continually throughout life and is called bone remodeling. This is illustrated in Figure 1 (Langton, 2000). The cycle may take only 2 months or last much longer depending on the bone involved. The distal part of the femur, as an example, is remodeled every four months. According to how much stress has been applied to the bones, new bone will be formed. Athletes tend to have thicker, heavier bones than non-athletes. The two functions of remodeling, apart from healing injury, are to renew bone before it becomes too damaged and to realign the bone matrix with lines of mechanical stress (Tortora, 2000) in order to increase it's resistance to impact during trauma.

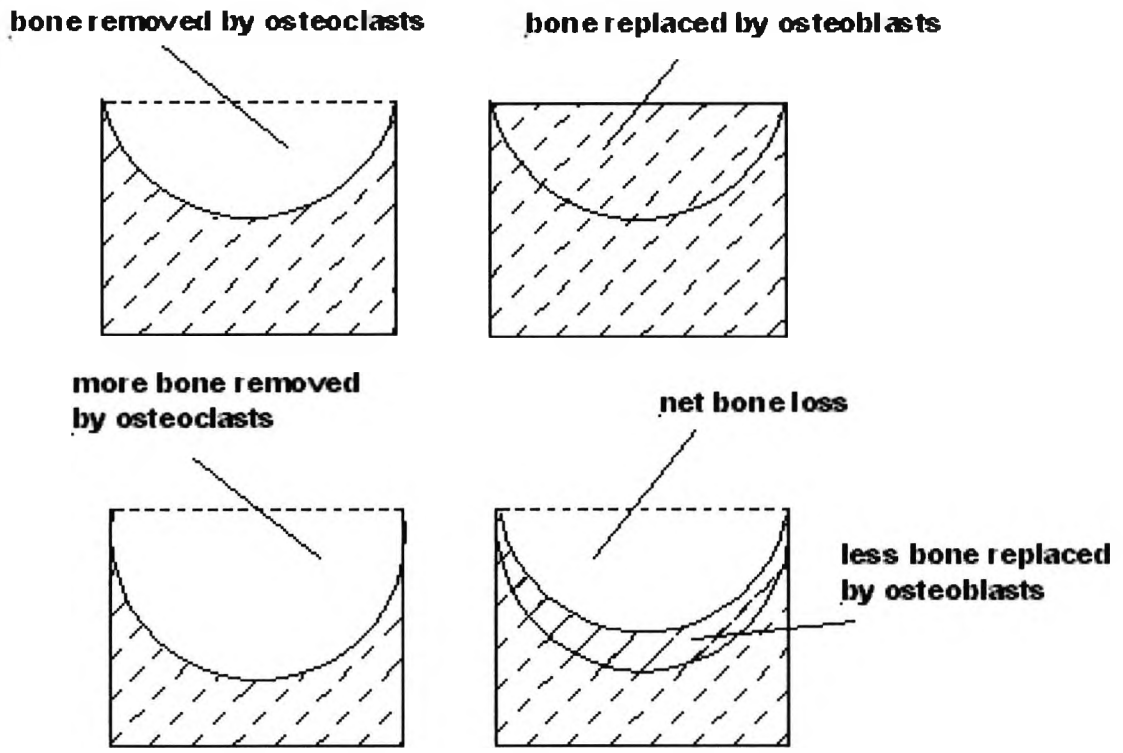


Figure 1 Bone Remodeling

A team of cells that dissolves an area of bone and then fills it in is described as a Basic Multicellular Unit (BMU) by Ott (2006). The process of remodeling is instigated in quietly resting bone, for example by damage caused by stress at the microscopic level. Osteocytes embedded in the bone structure send chemical messages out which stimulate stromal cells to ultimately produce osteoclasts and osteoblasts. Osteocytes sense mechanical stress through their long processes embedded in bone matrix. Some chemicals may also activate the stromal cells, such as parathyroid hormone. Mature osteoclasts, with their rough border, secrete hydrogen ions and cathepsin into a space in the bone matrix which they create. Osteoclasts live for about 2 weeks performing this function and then undergo apoptosis. This death is delayed if oestrogen is insufficient, which would allow resorption to continue. Osteoblasts then fill up the cavity with osteoid. When it becomes about 6 microns thick the osteoblasts cause it to mineralize. After the cavity has been filled it continues to increase in density for many months.

To maintain an even level of bone, osteoclast action must be balanced by osteoblast action. Too much bone formation causes thickened bones and sometimes bone spurs. Too little bone formation, or inadequate calcium, leads to weakened bones and

ultimately fracture. It is the outcome of bone remodeling, as well as bone growth, which will be studied in this thesis by attempting to quantify bone quality and strength. The factors which have affected the remodeling and growth of bone are the independent risk factors being measured, two of which are physical exercise and calcium intake. These factors, and their influence on the bones, will be explained in more detail in later chapters.

The way remodeling is controlled by the body is complex but includes sex hormones, parathyroid hormone (PTH) and activated vitamin D or 1,25 dihydroxycholecalciferol (1,25 DHCC). PTH and vitamin D influence the calcium levels in the blood. Vitamin D increases dietary calcium absorption through the gut although it has to be modified in the liver and kidneys in order to be active. Of several vitamin D compounds, D_3 is the most important. The skin, when exposed to ultraviolet radiation from the sun, forms D_3 from 7-dehydrocholesterol (Guyton, 1982). In the UAE, females usually cover their bodies, often from head to foot, and therefore can become vitamin D deficient causing bone weakness. Length of time of sun exposure per day is a lifestyle factor under investigation in this project. For the formation of active vitamin D to be completed in the kidneys, PTH is required. The role played by active vitamin D takes place in the intestinal epithelium in the promotion of calcium absorption. The precise details of calcium absorption are not fully known but one of the things which vitamin D does is to cause the formation of a calcium binding protein which helps calcium to be absorbed (Guyton, 1982).

The sex hormone oestrogen encourages cell death of osteoclasts, which slows resorption and helps formation of bone. Calcium is not only important to bone but is vital to the normal bodily function of nerve cells, enzymes and blood clotting. The majority of calcium in the body, 99%, is stored in the skeleton but when circulating blood plasma levels of calcium ions drops below 9mg/100ml this will trigger the release of calcium back into the blood. PTH, through negative feedback, mainly controls this system of calcium exchange. By increasing the number and activity of osteoclasts, bone resorption increases and more calcium enters the blood. The opposite effect occurs with the hormone Calcitonin which the thyroid secretes when calcium blood levels are too high (Tortora, 2000). Osteoporosis results from an abnormality in the remodeling process of bone in which bone resorption exceeds bone formation

leading to a net loss of bone (Simon, 1998). Cancellous bone is lost at a much faster rate than cortical bone since the structure is less compact, therefore most fractures occur in cancellous rich bone sites. Some examples are the neck of the femur (a site often fractured in elderly women), vertebrae and calcaneum.

Figure 2 is a picture of normal cancellous bone in a vertebral body (Langton, 2000) showing a well connected lattice work of trabeculae. Figure 3 shows a picture of osteoporotic cancellous bone (Langton, 2000); note the larger spaces between trabeculae than in Figure 2. The trabeculae are thicker and there are less connections between them which causes the mechanical structure of the matrix to be weaker than a well-connected one.

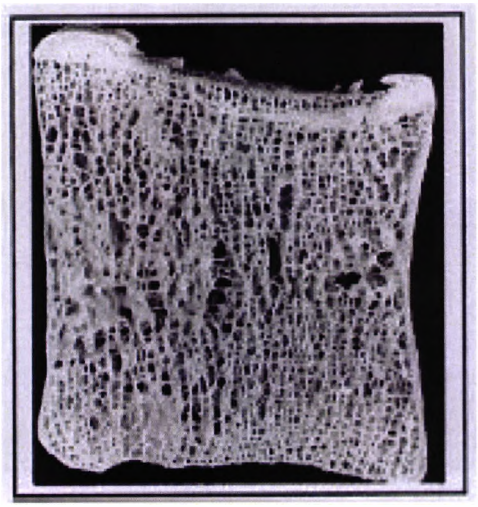


Figure 2 Normal Cancellous Bone

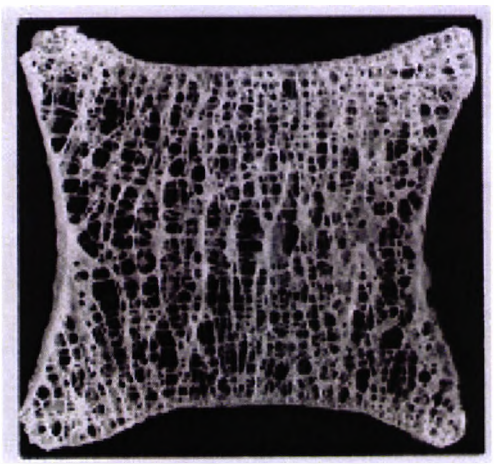


Figure 3 Osteoporotic Cancellous Bone

The following section will introduce the environment necessary for maintaining healthy bone tissue.

1.2.3 Bone Growth and Maintenance

A well balanced diet throughout childhood is needed in order to supply the vitamins and minerals required to build healthy bones. After reaching PBM bone will begin to be lost, so storing enough bone for the rest of adult life is essential. Calcium, phosphorous and to a lesser extent fluoride, magnesium, iron and manganese are all required as well as vitamins C, K, B_{12} and A. Several hormones are involved in the process of childhood bone growth and they are insulin like growth factors (IGFs), thyroid hormones and insulin. Human growth hormone (hGH) from the anterior pituitary gland stimulates IGF production. A disruption in the supply of any of these hormones may interfere with normal bone development and for that reason students suffering from thyroid, pancreas (diabetes) or pituitary conditions were to be excluded from the study, full details of exclusions will be found later in the section on methodology.

The sex hormones, oestrogen in females and androgens in males (a group of steroid hormones including testosterone and androsterone), begin being produced by the reproductive organs at puberty and have an important effect on bone. In fact both hormones are found in either gender as females also produce small amounts of androgens in the adrenal glands and males convert some androgens in adipose tissue to oestrogen. Sex hormones promote bone growth and it is because of the abundance of oestrogen in females that they reach full growth before males. The rapid reduction in oestrogen at menopause has the opposite effect and accounts for women suffering higher losses of bone more rapidly than men. The sex hormones, as mentioned earlier, encourage cell death of osteoclasts which slows resorption and helps formation of new bone (Tortora, 2000).

1.2.4 Bone Loss

If there is an imbalance in bone remodeling and bone resorption exceeds formation then there is a resultant loss of bone. According to the cause, the bone loss can be divided into four clinical types which are: 1/ osteopaenia (a decrease in osteoid

formation), 2/ osteomalacia (a decrease in mineralization of osteoid), 3/ osteolysis (an increase in removal of bone by osteoclasts) and 4/ osteoporosis (a loss of bone tissue) (Duckworth, 1995).

Osteopaenia may be caused by a deficiency in the diet of vitamin C, ascorbic acid, which in turn inhibits collagen synthesis and bone formation (differentiation of osteoblasts into osteocytes). Ascorbic acid stimulates the synthesis of a constituent of collagen called hydroxyproline. It also helps in the cementing together of bone cells in the matrix. If the body is denied vitamin C for 20 weeks or more, as used to happen to sailors on long voyages years ago, a condition results called scurvy. Malabsorption syndromes can inhibit vitamin intake, including vitamin C, also causing osteopaenia (Guyton, 1982). Another cause of osteopaenia may be Cushing's syndrome (excess amounts of corticosteroids produced by the adrenal cortex) or steroid therapy causing greatly decreased tissue proteins almost everywhere in the body, including the bones (Guyton, 1982). Disuse atrophy (Duckworth, 1995) causes osteopaenia also through immobility either from injury, disease or physical handicap. As has been described previously, the bones respond to mechanical loading from physical exercise and when there is no exercise they weaken and this can become osteopaenia.

Osteomalacia is caused by a lack of vitamin D and can be due to insufficient dietary intake of vitamin D (vitamin D increases calcium absorption by 30-80% and is therefore crucial to maintaining adequate levels of calcium in the body), or by lack of sunlight which stops the body from manufacturing its own active vitamin D (Osteoporosis Society of Canada, 2001). It should be noted that bone measurements cannot differentiate between osteopaenia and osteomalacia, only laboratory tests could reveal such information.

Osteolysis occurs when bone is lost by one of the following: 1/ disease, 2/ infection or 3/ ischaemia (loss of blood supply). Whilst both osteopaenia and osteomalacia are discovered in otherwise healthy individuals, osteolysis has an underlying pathology, such as cancer, affecting the bone tissue in localized areas, which are visible on X-ray images as a lucency.

Osteoporosis is the term which is used to describe the condition of extremely porous or

thin bones and may be due to any of the above pathologies. The definition of osteoporosis in terms of bone density measurement has been briefly mentioned earlier and will be discussed again in more detail later in this work. It is not expected that osteoporosis be present in healthy young people however other studies in the Gulf States around the UAE have shown high incidences of osteopaenia and osteomalacia (Bererhi 1994, Ghannam 1999, Saadi 2001 and Shilbayeh 2003). Osteopaenia precedes osteoporosis. Osteopaenia is mild bone loss and osteoporosis severe bone loss with increased susceptibility to fracture from minimal injury.

1.2.5 Causes of Osteoporosis

There are several known causes of osteoporosis but the reason that osteoporosis is present in such epidemic proportions is, as already mentioned, that bone is lost normally with increasing age. Osteoporosis is either primary or secondary. Primary osteoporosis can be divided into Type I and Type II (refer to Table 1). In Type I the increased loss of bone is thought to be related to a drop in gonadal hormone levels (post menopause in women or in the rare situation of castration in men). Type II occurs with gradual loss of bone during ageing and is seen more after the age of 60 (Simon, 1998). In Table 1 the different types of osteoporosis are shown with their descriptions (Simon, 1998).

Type I	Type II
• Endocrine-related • Postmenopausal women • Trabecular bone loss with vertebral body and wrist fractures	• Age-related • Men and women >60 years • Cortical and trabecular bone loss with hip fractures

Table 1 Types of Osteoporosis

Secondary osteoporosis occurs as a result of a disease or from iatrogenic (side effect from treatment) causes. Table 2 lists some known causes of secondary osteoporosis.

A wide variety of conditions are associated with osteoporosis and this was taken into

account when selecting subjects for the study. Subjects to be included would need to be healthy volunteers without any of the conditions known to affect bone strength.

Disorders that contribute to osteoporosis
Hypogonadism
Hyperadrenocorticism: primary, iatrogenic
Hyperthyroidism (and excessive thyroid hormone replacement)
Intestinal malabsorption syndromes
Vitamin C deficiency (Scurvy)
Calcium deficiency
Prolonged immobility
Disorders caused by chronic ingestion of anticonvulsant drugs
Adult hypophosphatasia
Disorders associated with other metabolic bone diseases;
osteomalacia e.g. Vitamin D deficiency,
hyperparathyroidism
Hypercalciuria
Heritable connective tissue disorders associated with osteoporosis
Various forms of osteogenesis imperfecta
Other systemic disorders or states associated with osteoporosis
Rheumatoid arthritis
Diabetes mellitus
Chronic hepatic diseases (including primary biliary cirrhosis)
Alcoholism
Down's syndrome
Chronic pulmonary disease
Multiple myeloma

Table 2 Classification and Causes of Osteoporosis

2. PREVALENCE OF OSTEOPOROSIS

2.1 Prognosis

2.1.1 Fractures

Osteoporosis is often called the silent disease because bone loss occurs without symptoms. People may not know that they have osteoporosis until their bones become so weak that a sudden strain, bump, or fall causes a fracture or a vertebra to collapse. Collapsed vertebra may initially be felt or seen in the form of severe back pain, loss of height, or spinal deformities such as kyphosis or stooped posture (National Institute of Health, 2000). Pain is a debilitating symptom of osteoporosis. It occurs following a fracture. It is important to note, however, that pain does not normally occur due to bone loss itself, hence the term silent disease (Compston, 1999: 26).

A fracture is a break in a bone. The incidence of fractures during life is bimodal, peaking first in young people aged between 15 and 25 and then in the old aged of over 85 (ISCD, 2003). Any bone in the body can fracture but in osteoporosis the most common sites are the spine, hip, wrist and proximal humerus. A wrist fracture can occur when the patient falls forward onto an outstretched arm. This type of wrist (distal radius) fracture is called a Colles fracture. Most wrist fractures can be effectively treated and normal use will return to the area. However, sometimes the ends of the bone do not unite well causing a deformity. Algodystophy (nerve injury causing exquisite sensitivity) occurs in one third of wrist fractures and produces tenderness, swelling, stiffness and sometimes circulatory problems (Compston, 1999: 26-27).

Fractures of the spine most commonly occur in the mid and lower thoracic and the lumbar vertebrae. When the bones are already thin, the slightest trauma can cause a fracture, including lifting, jumping or sudden movements. In 30% to 60% of spine fractures the cause has been a fall. These fractures can cause severe pain not just at the site but also radiating out to the abdomen. The pain is intensified by movements such as coughing, bending or prolonged sitting. Persistence of a nagging pain for many years is not uncommon (Simon, 1998). Spine fractures are different to fractures of other bones. The bones do not break but due to their weakness they crush or compress. The shape they take after fracturing is described as "codfish vertebrae" which is an

exaggerated biconcave shape. Fracture may also cause flattening and "wedging" of the vertebrae leading to kyphosis (excessive outward curvature of the spine, causing hunching) of the thoracic spine (Simon, 1998). Figure 4 is an X-ray image of the lateral lumbar spine showing the concave shape of osteoporotic vertebrae, which would normally appear more rectangular in shape (Simon, 1998). When several vertebrae are affected with osteoporosis, height can be lost. The amount can vary from one or two inches up to six inches or more.

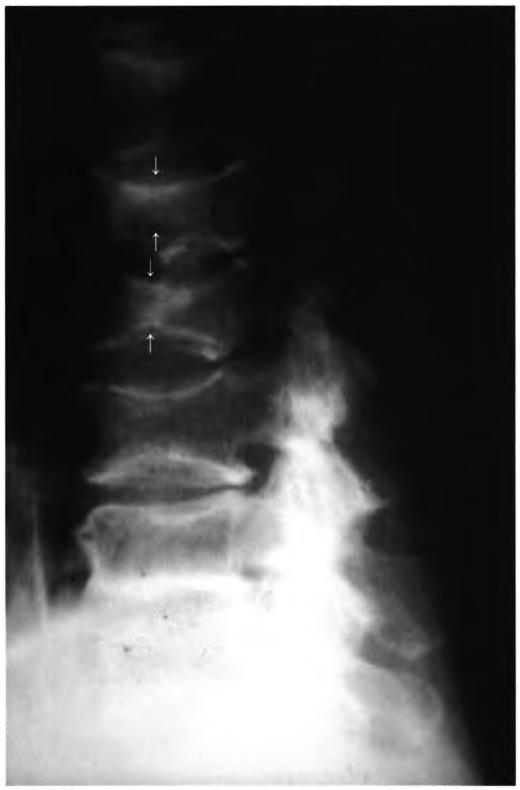


Figure 4 Compression Fracture (Codfish Vertebrae)

The consequences of vertebral fractures are as follows: 1/ back pain, 2/ loss of height, 3/ kyphotic back deformity causing the abdomen to protrude, 4/ reduced lung function due to the poor posture incurred from kyphosis, 5/ loss of self esteem and poor quality of life leading to depression and loss of independence and finally, 6/ increased mortality. Sadly, vertebral fractures are commonly underdiagnosed. Of all spine fractures which can be detected on plain X-ray films, only 30% are recorded in the X-ray report by the radiologist (ISCD,2003).

Fractures of the hip occur commonly in elderly people as a result of a fall. The fracture

has to be surgically repaired. The patient needs to be hospitalized for 3-4 weeks as a minimum and complications often arise.

2.1.2 Mortality and Economic Implications

Taxel (1998) states that osteoporotic fractures are associated with high rates of morbidity and mortality and that within 1 year of hip fracture, excess mortality rates range from 12% to 37%. Spine and wrist fractures cause significant morbidity, but hip fractures are much more serious in terms of increase in mortality, 15% to 20% as described by Kanis *et al* (1997). The statistics on osteoporotic fractures are shocking. In America, almost 65,000 women die yearly from complications of hip fracture. Of the hip fracture survivors, 50% are permanently incapacitated and 20% of them are placed in nursing homes. As well as variations in type of fracture that occur there are three other variations in incidence rates. Firstly, women suffer more fractures than men partly perhaps because their bones are smaller. Secondly, some races may suffer more fractures than others. This concept has been introduced earlier, but to recap, it was that ethnicities differ e.g. Africans have higher bone mass than Europeans, and consequently may suffer fewer osteoporotic fractures. Thirdly, there are variations in fracture rate according to geographic location. In Europe, Scandinavians have 7 times more fractures than people from other countries (ISCD, 2003). A possible explanation for this may be the weather, with colder weather in Scandinavia causing ice leading to falls. However, a lot of the differences in fracture rates still needs investigating as the full range of causes are unclear at present. Furthermore, research is needed on fracture incidence for each ethnic group to determine where the cut-off points are for actual bone strength to describe those at very high risk of fracture, i.e. osteoporotic cases.

It is not surprising that osteoporosis is receiving such attention as a serious condition when it is compared to other chronic diseases such as high cholesterol and high blood pressure. Figures from the United States (US) given in a review by Melton (1995) rated osteoporosis as third most common chronic disease at 28 million after hypercholesteremia with 52 million and hypertension with approximately 40 million sufferers. The next year Melton (1996) noted that, for Caucasian women over 65 years of age, hip fractures were more common than stroke, breast cancer and diabetes. The risk for women over lifetime, of suffering an osteoporotic fracture, which is 40%, is

greater than the risk of having any of either breast, endometrial or ovarian cancer (ISCD, 2003).

The cost to the health care system arising from osteoporotic fractures is enormous, and has been rising. According to the study by Kanis *et al* (1997) hip fractures accounted for more than 20% of orthopaedic beds in several countries, including the UK. In fact, they stated that after the age of 45 years, hip fractures account for a higher proportion of hospital bed occupancy than many other common disorders in women, including breast cancer and diabetes. According to Wekslar (1997) more than 250,000 hip and 600,000 vertebral fractures occur in the US in postmenopausal women. In men, about one third of the number of fragility fractures are seen, which gives a total number of 1 million people suffering from fragility fractures. They estimate the cost to be above $10 billion for acute hospital care and rehabilitation.

Three years later, the National Institutes of Health (2000) reported that in the US then, 10 million individuals already had the disease and 18 million more had low bone mass, placing them at increased risk for osteoporosis. The report estimated the cost to hospitals and nursing homes from osteoporotic fractures at $13.8 billion ($38 million each day) and rising. These costs do not take into account loss of wages during time off work nor the impact on business of the lack of workforce caused by sick leave.

Osteoporosis warrants intense scrutiny in the UAE to determine the extent of the mortality and economic implications for this population in order to plan public health measures to lessen the impact of the disease.

2.2 Diagnosis

2.2.1 Symptoms

In the National Osteoporosis Foundations Physician's Guide to Prevention and Treatment of Osteoporosis (2000) it states that all women should be counseled on the risk factors for osteoporosis because osteoporosis is a "silent" risk factor for fracture, just as hypertension is for stroke.

The first sign that osteoporosis is present is a fracture. However, osteoporosis is preventable and treatable. Unless the public understand the risks associated with an unhealthy bone lifestyle then osteoporosis will continue to be a huge burden on health care provision and the economy.

This thesis is based on the ideal of osteoporosis prevention. The assumption has to be made, in the lack of research knowledge, that the inhabitants of the UAE are subject to the same set of circumstances regarding bone strength and later onset of osteoporosis as other more studied ethnicities. It is true that the same environmental characteristics which affect bone are present in this rapidly developing country, mainly the change in diet and exercise habits of the younger generation to more sedentary behaviour and increasing dependence on fast foods. Section 1.4.3 will introduce the lifestyle risk factors internationally thought to influence negatively on bone strength.

2.2.2 Measurement of Bone Strength

In order to diagnose osteoporosis, or low bone strength, measurements of different bone parameters can be taken with commercially available medical equipment. The techniques available, and equipment selected for this research project, are found in a dedicated section entitled Bone Strength Measurement later in this thesis but in order to read and understand the descriptions of current research mentioned in the following sections, the two main bone strength measurement techniques should be named. These are:- 1/ Quantitative Ultrasound (QUS) which is a technique usually performed on the calcaneum and gives a result of stiffness of bone or sometimes estimated bone density, and 2/ Dual Energy X-ray Absorptiometry (DXA) which is a technique usually performed on the spine and hips and gives a result of bone density measured in g/cm^2. It is currently the gold standard method of measurement according to the World Health Organization (WHO).

2.2.3 Factors Influencing Bone Strength

2.2.3.1 Peak Bone Mass

Mackelvie (2001) made the astute observation that osteoporosis may be more accurately described as a disease of inadequate bone accrual rather than excessive bone

loss. The comment has been made that genetic factors account for as much as 80% of the variance in peak bone mass accrual (Compston, 1992). Another factor which has been suggested as affecting peak bone mass is intrauterine development due to the link between birth weight, childhood growth rates and peak bone mass (Cooper, 2001). The main point regarding peak bone mass is that the more bone that can be built up during childhood and adolescence, the longer it will be in years before osteoporotic bone mass is reached. In view of the comments in the previous section detailing low levels of exercise, it is relevant to try to determine some preliminary information on UAE PBM.

2.2.3.2 Carbonated Drinks and BMD

Wyshak (2000) demonstrated that in 460 high school girls, those who consumed carbonated beverages had an increased fracture risk of 3 times normal, and that there was particular risk for cola beverages. It is thought that the process of manufacturing carbonated drinks which uses phosphoric acid could account for this discovery as phosphoric acid can adversely affect calcium metabolism and bone mass. However, the flaws in the study were many including the lack of information regarding calcium intake in these girls, no assessment of other osteoporosis risk factors or BMD assessment and the fact that the fractures were unproven and self-reported.

2.2.3.3 Respiration and BMD

From a large UK study which recruited 4,830 females between the ages of 45-76 years, a possible new predictor of BMD has been suggested (Lekamwasam, 2002). A positive correlation was found between total hip BMD and forced expiratory volume FEV (1). This association was independent of other BMD factors. An FEV (1) increase of 1 l/s gave an increase in BMD which was equivalent to a reduction in age of 6 years or an increase in weight of 5kg. As the article surmised, it could be that FEV (1) was representing physical activity but whatever the mechanism, this could be a simple marker for osteoporosis risk and warrants further study.

2.2.3.4 BMD of the Shoulder

Doetsch *et al*, 2002, have investigated BMD measurement of the shoulder, whilst looking for areas of least BMD. The shoulder is subject to a lesser load than the hip and they did find shoulder BMD values to be significantly lower than hip BMD for the same subjects, a difference which increased with increasing BMI. They suggested

shoulder BMD to be a better indicator of early osteoporosis.

2.2.3.5 Bone Geometry

Whether or not a fracture will occur in a bone is not only dependent on BMD. More than just the density of a bone determines if a fracture occurs. With this in mind, some researchers have considered the geometry of bones in order to look for differences which could be additional factors linked with fracture. One such study by a group at Cornell University focused on the femoral neck of adolescents (van der Meulen *et al*, 2000). An evenly divided group of 101 healthy young people from 9 to 26 years were recruited for study. Body mass, calcium intake, pubertal stage and physical exercise were all recorded for the group. From DXA scans of the femur, the hip axis length and femoral neck bone width were measured. Finally an index of neck strength was calculated which was indicative of the force required to fracture the neck of femur. The study found a correlation between lean body mass and femoral structure, but interestingly did not find a link between neck structure and weight bearing exercise, presumably because structural parameters are genetically defined and non-modifiable.

2.2.4 Blood and Urine Tests

The main method of diagnosing osteoporosis is bone density measurement, which will be discussed in more detail in the following section. There are laboratory tests which offer information regarding some bone parameters but they have been proven not to be suitable for diagnosis of osteoporosis. It may be possible for bone turnover markers to be used as an adjunct to bone mineral density however these tests cannot be used alone for diagnosis. Laboratory tests are required when osteoporosis has been diagnosed in order to determine if it is secondary to another underlying condition such as a malabsorption syndrome or osteomalacia as a result of vitamin D deficiency.

Test	*Measurement of:*
Serum thyrotrophin TSH	• Level of thyrotrophin in the blood (TSH - synthesized by the anterior pituitary gland) which stimulates thyroid function.
Protein electrophoresis	• Analysis of proteins in blood
Parathyroid hormone PTH	• Level of parathormone in the blood (PTH – synthesized by the parathyroid glands) which controls distribution of calcium and phosphate in the body. • High level – calcium from bones to blood • Low level – low blood calcium levels
Vitamin D level	• Vitamin D_2 – ergocalciferol, manufactured by plants • Vitamin D_3 – cholecalciferol, produced by the action of sunlight on the body
Urine calcium	• Amount of calcium excreted as a waste product in the urine
Cortisol	• A steroid hormone released into the blood by the adrenal cortex

Table 3 Biochemical Tests for Bone Markers

The other important use for lab tests is for monitoring patient's response to osteoporosis drug therapy. The physiological markers which can be monitored are enzymes or proteins secreted by bone cells – osteoblasts or osteoclasts; substances produced during the formation or breakdown of collagen.

Alternatively, they can be considered as markers for bone formation or resorption (American Medical Association, 1999). Some biochemical tests are listed in Table 3. Laboratory tests for bone information will not be examined in any detail here as no lab tests were used for this study. They may be employed in future research whenever an underlying cause of osteopaenia is being sought such as vitamin D deficiency.

2.2.5 Screening

Screening means to test large numbers of healthy people to look for the presence of a disease. Asch (1998) suggests that osteoporosis fits Frame and Carlson's (1975) six criteria for a disease, which are listed in Table 4, for which there should be routine screening. For a disease to be worthy of screening, there must be a treatment available.

Frame & Carlson's Screening Criteria
• The disease must be common
• The disease must be costly
• The natural history of the disease must be known
• The screening tools must be available, reliable, affordable
• The interventions must be effective
• Cost saving must have been documented

Table 4 Frame and Carlson's Screening Criteria

It should be remembered that there is no point screening for a disease unless the candidate has agreed to the treatment method, should it be required. This statement is particularly relevant in the case of hormone replacement therapy, one of the treatment options which has recently become controversial (Million Women Study, 2003). Decisions about who to treat require an assessment of bone mineral content to most accurately predict or diagnose osteoporosis. The current noninvasive gold standard for the diagnosis of osteoporosis is dual X-ray absorptiometry of the hip or lumbar spine (Asch, 1998).

2.3 Awareness and Treatment

2.3.1 The United Arab Emirates

Differences in bone mass and prevalence of fracture are seen between different ethnicities. Persons of African decent have been shown to have higher bone mass and lower rates of fractures. Asian women have lower bone mass than Caucasian women and the worldwide risk of hip fracture varies greatly (Ott, 2001).

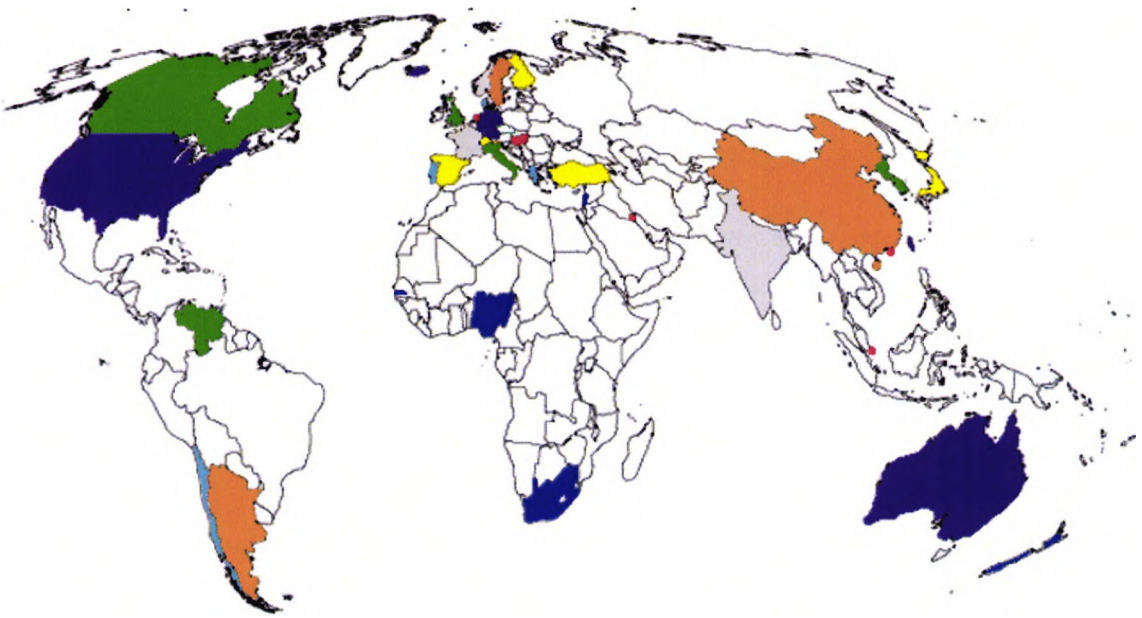


Figure 5 Map Showing Availability of Hip Fracture Information by Country

Figure 5 highlights the lack of information for many areas of the world on fracture risk (Ott, 2001). Areas without colour are without recorded hip fracture information. The nearest country to the UAE with recorded information is Kuwait. This serious health issue remains to be investigated for the UAE population. It is hoped that in the near future some research could be initiated to describe fracture incidence in this country, and correlate results to the associated risk or likelihood of fracture.

Since Islam, to varying extents, dictates lifestyle choices and behaviour such as sun exposure in women, Arabs cannot be assumed to be the same as Caucasians and should be independently investigated for bone strength.

2.3.2 Population

The population of the UAE has been growing steadily over the years. In 1975 the total population was 558,000 but by the year 2000 it had increased to 3,100,000. The population of Sharjah, which is the third largest emirate following Abu Dhabi and Dubai, has followed the same trend in population increase and in 2000 had a total of 520,000; 331,000 males and 189,000 females. Sharjah had 16.7% of the UAE population (Research and Studies Department, Dubai Chamber of Commerce and Industry, 2000). The population estimate for 2003 was just over 4 million according to the Ministry of Planning (2003): 636,000 in Sharjah and 1,200,000 in Dubai. In almost

all of these years the number of males has been approximately double the number of females. Table 5 below shows population statistics compiled by the Ministry of Planning, Government of the UAE. Bearing in mind that there are twice as many males than females, the inclusion of men in this research project is deemed important. It is thought that around 80% of the population are expatriates leaving only approximately 800,000 UAE nationals, many of them Arabs from surrounding countries. Studying all Arab students in the UAE is therefore relevant. The proportion of males to females is due to the expatriate workforce which consists mainly of men. As can be seen in Table 8, except for the first and last rows which are of ages below or above normal working age, the number of men far exceeds the number of women. Some rows have been omitted from the original table but the totals are correct.

السكان حسب فئات العمر والنوع

POPULATION BY AGE GROUPS AND SEX

فئات العمر	تعداد	1995			*2001			*2002			*2003		
AGE GROUPS	ذكور Males	إناث Females	جملة Total	ذكور Males	إناث Females	جملة Total	ذكور Males	إناث Females	جملة Total	ذكور Males	إناث Females	جملة Total
15 - 19	83,438	75,471	158,909	117,535	103,947	221,482	125,689	111,065	236,754	134,617	118,322	252,939
20 - 24	139,868	77,882	217,750	205,255	110,208	315,463	221,234	118,390	339,624	238,826	126,893	365,719
25 - 29	238,104	88,409	326,513	354,351	126,661	481,012	382,901	136,391	519,292	414,304	146,607	560,911
30 - 34	229,066	80,213	309,279	341,983	114,836	456,819	369,786	123,656	493,442	400,361	132,934	533,295
35 - 39	219,961	68,740	288,701	328,447	97,815	426,262	355,206	105,227	460,433	384,644	112,995	497,639
40 - 44	161,583	41,646	203,229	241,027	59,131	300,158	260,622	63,592	324,214	282,214	68,262	350,476
45 - 49	106,166	25,850	132,016	157,819	36,345	194,164	170,542	39,012	209,554	184,555	41,788	226,343
50 - 54	51,655	13,694	65,349	76,311	19,006	95,317	82,372	20,346	102,718	89,068	21,724	110,792
55 - 59	25,046	8,344	33,390	36,475	11,450	47,925	39,266	12,231	51,497	42,332	13,021	55,353
60 - 64	10,407	5,553	15,960	14,776	7,552	22,328	15,824	8,047	23,871	16,969	8,549	25,518
65 - 69	6,492	4,597	11,089	8,942	6,214	15,156	9,521	6,617	16,138	10,135	7,019	17,154
70 - 74	3,651	3,180	6,831	4,943	4,280	9,223	5,245	4,549	9,794	5,566	4,817	10,383
الجملة Total			2,411,041			3,488,000			3,754,000			4,041,000

* تشير التقديرات الى منتصف السنة

* Figures are mid-year Estimates

Table 5 Population of the UAE by Age Groups and Sex.

2.3.2.1 Student Population

Between 2002 and 2003, 52,000 students were estimated to have completed high

school education. A very high proportion of Arab young people receive further education. It is for this reason that studying students is so relevant, as they could be considered to be representative of all young people in the UAE. It can also be seen from the above table that there are much higher numbers of younger people than older. As the country is relatively young but expanding its population greatly year on year, the full impact of osteoporosis has not yet hit. As the number of old people grows, osteoporosis will increase in prevalence.

2.3.3 Culture

Almost all nationals wear national dress. For women this means that they cover their head and body. The long robe worn over the body is known as an Abba or Abaya. The head cover is the Burqa. Some women will totally cover their face, hands and feet from view whilst others only cover their hair (Mathew, 1999: 31). Full cover of all skin leads to an automatic risk for osteoporosis due to vitamin D deficiency from lack of exposure to the sun. The expatriate women wear a variety of dress from Abaya to Western, but females on the academic campus seem to dress conservatively and don the Abaya even if they do not usually wear it at home. Consequently, the great majority of female students are covered. Further than that, covering can also be continued in the home and for a religiously conservative woman to gain sun exposure at her home there would have to be a designated female only area outside but within her home confines, which could not be viewed by any man including all male family members other than her husband.

2.3.4 Healthcare

In 1996, ArabNet stated that due to improving healthcare in the UAE since the discovery of oil in 1962, investment in health care has been enormous and includes a country-wide health education programme and easy access to all kinds of medical care. The World Health Organization (WHO) believed that the UAE was well on the way to attaining WHOs target of "Health for All by the Year 2000" at that time.

The Federal Government Ministry of Health (MOH) provides health care for all the Emirates through hospitals and clinics. These are controlled federally by Abu Dhabi and locally by the Medical District of each Emirate. There are nine hospitals for

Sharjah and the Northern Emirates, the main two being Al Qassimi hospital for nationals and Kuwaiti Hospital for non-nationals.

As well as being serviced by the federal system, Dubai has its own health care system – the Dubai Department of Health and Medical Services (DDOHMS). It has four hospitals under its control. This DDOHMS health authority is totally independent of the federal system – the Ministry of Health.

There are several private hospitals and clinics throughout the Emirates, of varying standards. One hospital in Dubai, the American Hospital, has received Accreditation by the Joint Commission on the Accreditation of Healthcare Organizations (JCAHO) in America. The American hospital has also become the first and only hospital in the Middle East to be accredited by Joint Commission International Accreditation (JCIA) a division of the JCAHO (MEH, 2000).

In 2002 there was at least one DXA machine in the private sector, in a rheumatology clinic in Sharjah, but since government health care is free, UAE Nationals do not tend to use private medicine as a rule. Should a national require DXA he/she would be referred to the nearest available equipment, probably in Al Ain. This is more than one hours drive away. Consequently, not many people were aware of, or had accessed, BMD testing.

In 2005 the situation changed slightly in that Al Qassimi hospital acquired a software package which enabled them to perform quantitative computed tomography (QCT) bone density measurements. However, the CT scanner is extremely busy and because of the higher dose received by the patient from QCT compared to the gold standard method of DXA, QCT is not being widely used. A DXA machine was installed in the federal hospital in Dubai (Al Baraha Hospital) and another one in one of the DDOHMS hospitals (New Dubai Hospital) in Dubai but Sharjah remains without government DXA access locally. Patients from Sharjah could be sent to the new facility in Dubai at the Dubai Hospital but not to Al Baraha. In September 2005 the Dubai Hospital DXA scanner had only been in service for a few months and this installation occurred after the data collection had finished for this project.

2.3.5 Health Status

Typically, a UAE wife's work is a mixture of cooking, socializing and raising a family. Daily shopping is done by the men, who often buy in bulk the basic commodities, such as rice and flour, fruit and vegetables. Women are escorted by friends or a member of the family when they go out (Mathew, 1999: 36).

The author's observations suggest that the UAE female leads a very sedentary life, causing a further risk for osteoporosis due to lack of exercise. Discussion with the University female students at Sharjah indicated that although physical exercise was part of the curriculum in high school, participation was not 100%. Further, although the University is equipped with state of the art sports facilities, many of the students reported not using them at all. With the benefit of oil, and financial security, the majority of households have hired help. Walking outside in this country is not possible most of the year due to the intense heat. Perhaps due to the layers of clothing, in black which absorbs heat, UAE women tend to move sedately. The UAE does not accommodate walking outside as there are very rarely any pavements. Most outings consist of being driven to the door of the shop or house to be visited. Caring for children, which can be a very physical activity (lifting, carrying), is often almost entirely done by a live-in housemaid who may work 7 days a week for the family. These housemaid positions are filled by expatriate, non-Arabs from countries such as India, Sri Lanka and the Philippines.

Traditionally, the diet in the UAE is well balanced and healthy. Breakfast usually consists of freshly made wafer thin pitta bread stacked up and soaked in butter, fetta cheese and olives, along with dates, honey, sometimes omelette, and fruit and coffee. Milk products are popular. In the winter, hot sweetened milk is served (Mathew, 1999: 36). The milk used, though, is generally condensed milk from a tin. The younger generation has access to a huge variety of fast food outlets, as found in any cosmopolitan city. Reliance on fast foods can lead to further risk of osteoporosis, due to insufficient intake of calcium.

This generation's diet is set to impact on the next generation's risk of osteoporosis as a recent study conducted by Jones *et al* (2000) showed a substantial association between

poor maternal diet during the third trimester and low bone mass in eight year olds.

2.3.6 Osteoporosis Treatment

Currently, there is not a treatment that can cure osteoporosis. The aim of treatment is to slow down bone loss and to try to rebuild some bone. It is because bone cannot be significantly replaced that the change of focus to prevention of bone loss has occurred. More importantly, and the subject of this research, it is vital that the maximum possible store of bone, or peak bone mass, should be accomplished for every adult. The more bone there is available, the longer it will take for normal ageing bone loss to cause osteoporosis.

Treatment does not necessarily have to be with pharmaceuticals. Non-pharmaceutical treatment is possible with lifestyle changes, easy to accomplish and of prime importance in this research, which have been introduced earlier. They include adequate dietary intake of calcium, adequate vitamin D, reduction in caffeine intake, adequate levels of physical exercise and cessation of smoking. If osteoporosis is diagnosed and pharmacological therapy is required then the same drugs used elsewhere in the world are also available and currently are being prescribed in the UAE. An important consideration allied to drug therapy is the likelihood of the person falling and sustaining a fracture; fall prevention methods prove helpful in the frail to avoid fracture.

The author consulted the leading osteoporosis researcher in the UAE, Dr Hussein Saadi, to find out about treatment of low bone density. He stated that in his research the protocol for results which he used was that if a T-score was -0.9 and above the person was given reassurance that the result is within normal limits, if the T-score was -1.0 to -2.0 the candidate should visit their own doctor but only needs to take a calcium supplement, Caltrate, with vitamin D and for a score of -2.1 and below they should see their doctor for a full work up to investigate the cause of low bone density.

2.3.7 Osteoporosis Medication

Calcium and vitamin D are essential for bone health. Vitamin D supplementation is not required if sunlight exposure is adequate, however it may be taken by mouth or by

injection when necessary. It may be a combined product containing calcium also. Vitamin D itself is not active, nor is it a treatment for osteoporosis on its own. Calcitriol is an active form of vitamin D. It has been shown to prevent bone loss but it is very powerful and can lead to hypercalcaemia and hypercalciuria (causing kidney stones). Therefore, regular blood checks are needed whilst undergoing treatment (Compston, 1999: 76). Calcium supplements are not regarded as a treatment on their own either. However, calcium preparations are advised where the diet is lacking in calcium content. Side effects from calcium products are rare. It is common for a product containing both calcium and vitamin D to be prescribed in the UAE when osteomalacia is detected. Due to the importance of adequate dietary calcium and vitamin D it is normal for drug trials of osteoporosis pharmaceuticals to also ensure that participants receive the normal requirements of at least 1000mg of calcium and 400 IU of vitamin D as part of the study.

Hormone Replacement Therapy (HRT) is an effective way of treating osteoporosis in women deficient in oestrogen, for example post menopause. After menopause there is a decline in circulating oestrogen, which causes acceleration in the rate of bone loss. Prospective and retrospective long-term studies have shown that with continued oestrogen use over years, there is an increase in bone mineral density compared to placebo and a consequent reduction in fracture risk (Buckley, 1998). HRT refers to either oestrogen alone or a combination of oestrogen and progesterone medication. However, there is an increased risk of endometrial cancer when using oestrogen supplement which is reduced if progesterone is added (Compston, 1999: 57). There are, for those whom physicians consider at low risk for taking HRT, some health benefits. HRT was the treatment of choice for osteoporosis until fairly recently. However, in May 2002 the Women's Health Initiative study using Premarin and Provera for 5 years was stopped because there had been an unacceptably high increase in breast cancer and stroke causing the risk to be higher than the benefit from taking these medications (ISCD, 2003). Nowadays, it is not the preferred treatment and would be prescribed only if other symptoms warranted its use in a person at low risk from the known possible side effects.

Bisphosphonates (alendronate, etidronate and risedronate) are a group of drugs which are available for treatment which increase bone mineralization by binding to

hydroxyapatite crystals in bone and inhibiting bone resorption (Buckley, 1998). Bisphosphonates are not hormones and therefore do not carry the same risk. Bisphosphonates have now taken over as the preferred treatment in postmenopausal women but for patients for whom they are not suitable there is still the option of HRT. Alendronate sodium (tradename Fosamax) is prescribed to patients in the UAE. The effectiveness of alendronate sodium has been investigated for both ability to increase bone density (Liberman *et al*, 1995 and Tonini, 2000) and ability to reduce fracture incidence (Cummings *et al*, 1998). The increase in bone density was reported in these studies as more marked at the spine, around 8%, and less at the hip. The reduction in fracture incidence was marked at both anatomical sites and showed a 55% reduction in new spine fractures plus a 51% reduction in hip fractures. Currently, the dose is 70mg once per week but the bioavailability of the pharmaceutical in the body is not high and the patient must strictly follow the dosage instructions of both standing and nil by mouth for 30 minutes following administration of the oral dose. The other two bisphosphonates are not as effective as alendronate sodium although they have similar effects (Bonnick, 2004, pp 160-165).

Calcitonin is a hormone produced by the thyroid gland that stops the work of the cells that destroy bone. It prevents bone loss in the spine, but may be less effective in other parts of the skeleton such as the hip. It is not widely used for the long-term treatment of osteoporosis (Compston, 1999: 78). A large, 5 year study of Calcitonin effects called Prevent Recurrence of Osteoporotic Fracture (PROOF) was reported by Chestnut (2000). Calcitonin seemed to be effective in preventing fractures, showing a 36% reduction in new vertebral fractures, but did not show any significant increase in bone density for 1255 women.

Another option, Sodium Fluoride, is not at present commonly used as a treatment for osteoporosis. It increases bone formation (Riggs, 1990) and thus bone volume, but the quality of the bone generated is in question (Buckley, 1998). Preparations of fluoride include tablets and enteric coated or sustained release preparations. One preparation available is disodium monofluorophosphate (Kanis *et al*, 1997). Reginster *et al* (1998) concluded that low dose fluoride with calcium did decrease vertebral fracture rates in postmenopausal women although Meunier (1998) found that it had no effect. Fluoride as an addition to Raloxifene (Reginster, 2003) and Etidronate (Ringe, 2005) may offer

some increased benefits.

Selective Estrogen Receptor Modulators (SERMS) act like oestrogen but without the same side effects (increased risk of breast cancer, vaginal bleeding). Raloxifene is a SERM currently in use. It is structurally similar to tamoxifen and some short-term studies have suggested it may decrease the risk of breast cancer (Buckley, 1998). Delmas in 1997 studied the effect, on 601 postmenopausal women, of raloxifene with DXA examinations of bone density of the hip, femoral neck and spine. A gain in BMD of 2.2% was seen over 2 years. The Multiple Outcomes of Raloxifene Evaluation (MORE) study was much larger, including 7,705 postmenopausal women. The results as published by Ettinger (1999) showed an increase in spine BMD up to 2.6% at the end of 3 years. The femoral neck increase was less. Fracture incidence was reduced by 30% in the spine.

Anabolic steroids are a licensed method for treatment of osteoporosis but are not used often due to side effects of acne, fluid retention and abnormal liver function (Compston, 1999: 79). The anabolic steroid nandrolone decanoate was given to half of a group of twenty women, the rest receiving placebo. The increase in bone mineral content (BMC) seen in the spine was almost 10% in the steroid group compared to a loss of 3% in the others; an overall gain of 13% BMD (Gennari *et al*, 1989).

Parathyroid Hormone (PTH) 1-34 or teriparatide is a more recent entrant to the list of osteoporosis treatment options with perhaps the most impact on bone. Neer *et al* (2001) carried out a large study of 1,637 post menopausal women. The results were a 14% increase in spine BMD, 5% at the femoral neck and a huge, 69%, reduction in new spine fractures.

A new drug has the ability to both decrease bone resoption and increase bone formation, strontium ranelate. Ortolani (2006) found the efficacy of strontium, both early at 1 year and sustained at 3 years, to be demonstrated in postmenopausal osteoporotic patients. In a review by Burlet (2006) from the WHO Collaborating Centre for Public Health Aspects of Rheumatoid Diseases, strontium ranelate was considered to be a new first-line treatment for osteoporosis.

In summary, in cases of osteopaenia a supplement of calcium and vitamin D will be suggested and for lower bone densities requiring stronger pharmaceutical intervention the treatment of choice in the UAE is Alendronate Sodium, a bisphosphonate.

2.4 The Future

2.4.1 New Treatments

In spite of the availability of the previously mentioned drugs, work continues in order to find more efficient ways to resolve the problems of severe bone loss and fracture repair. Vertebroplasty is a fairly popular technique for vertebral fracture repair. It involves injecting a cement mixture (polymethylmethacrylate approved by the Food and Drug Administration) into the fractured vertebra and was the subject of a recent article in a weekend newspaper magazine in Octobers Gulf News (Anonymous, 2005).

Several new areas are being investigated for treatments. A hospital in Denmark (Jorgensen, 2002, Solgaard, 2005) has been pursuing the regulation of bone metabolism through P2 purinergic osteoclast receptors. These receptors are involved in cell proliferation, differentiation, activity and apoptosis and if these functions could be manipulated it would be an effective way of controlling bone tissue.

Pioneering work has been going on in London with human bone cells grown outside the body where a team from Hammersmith and Chelsea & Westminster Hospitals in London used a glass-like material which allows bone cells to grow and bond with each other quickly. In the future, researchers hope that the glass – enriched with bone cells and in liquid form – would be injected into patients with complex fractures to accelerate healing (Middle East Health, 2000: 6). A recent article in the Brazilian Dental Journal by Villaca (2005) described the successful use of bioactive glass particles which when implanted into premolar cavities in monkeys, showed that it stimulated regeneration by new bone. The University of Jena in Germany is the home of pioneering work in improving the acceptance of metal implants into bone when the receiver has compromised healing capacities, such as when osteoporosis is present. Sasche *et al* (2005) reported implanting titanium and bone cylinders, with and without a special protein coating, into the legs of aged, osteoporotic sheep. With the addition of

this newly developed coating, the implant initiated new trabecular bone and was 50% more stable than the non-coated implant.

The best option, however, for any individual, no matter how effective the treatments become, is to take measures to avoid low bone density and fractures altogether.

2.4.2 Genetic Research and BMD

A variety of different genes have been identified as being associated with BMD and they include; vitamin D receptor, collagen 1 α 1, oestrogen receptor, insulin-like growth factor 1 (IGF-1) and IGF-1 binding protein (Tuck & Francis 2002). It has been said that 80% of total bone mass is predetermined genetically (Lysen, 1997) including the factors of gender, ethnicity, body type and family disease history therefore in the future more and more attention will focus on genetic links. Understanding which people are predisposed to low bone density could greatly improve detection and facilitate more effective treatment or, better still, prevention.

Knapp *et al*, 2003, investigated 215 healthy pairs of female twins, 85 monozygotic and 130 dizygotic in order to determine if genetics influenced BMD. The twins had both QUS and DXA scans. They concluded that genetic influences were demonstrated for the SOS parameter of QUS in cortical bone at multiple sites and also for BMD of spine, radius and whole body.

Genetic and environmental determinants of peak bone mass were investigated by McGuigan *et al* (2002) in a cohort of around 500 young men and women. Spine and hip BMD were measured and compared to polymorphisms of the vitamin D receptor (VDR), oestrogen receptor (ER) and collagen type I alpha 1 (COLIA1) genes whilst taking into account lifestyle, exercise and birth weight. The study failed to show any links between the genes studied and concluded that other genes may yet be unidentified which control BMD. In this population, no genetic research on bone strength has yet been done.

2.4.3 Preventative Health

The Preventative Health Department in the MOH has been promoting public awareness

of osteoporosis since around 1998. Many articles have been produced since 2000 on the subject of osteoporosis both in local medical journals and in the general media. Symposia have been held on the subject. To date, osteoporosis is still receiving attention in local newspapers. As an example an article (Stolz and Squires, 2002) discussed the concern over high levels of vitamin A being associated with an increased risk of osteoporosis, as reported by the American Medical Association.

Doctors are aware of the problem of osteoporosis and the need for BMD equipment, however the healthcare system is still growing and there have been other more pressing needs for medical equipment, which have caused the provision of DXA equipment to be dropped to the bottom of the list (El Abbas, 2002). Currently, there is no DXA BMD measurement available in the Sharjah Medical District Government system. This contributes to the fact that there is a great gap in knowledge regarding bone density both in the normal population and for patients at risk.

January 2002 saw MRI machines finally installed in most of the Emirates government hospitals (this equipment has been available in the West for some considerable time) in-line with the UAE intention of trying to establish international levels of health care provision.

Middle East Health magazine (2000) wrote a feature article on osteoporosis. It mentioned that a major concern is that access to testing equipment and qualified technical personnel – and importantly reimbursement by medical insurance schemes – remains inadequate in many countries. This was certainly the case in the year 2000 in Sharjah.

In early 2005 the author participated in a MOH Preventative Medicine health awareness campaign run over several weeks in shopping centres in Sharjah. QUS heel scanning was offered free of charge, along with breast examination, blood pressure and diabetes testing. It was well received by the public and queues quickly formed at each session. It was observed that in many cases the mother's heel scan result was considerably higher than her daughter's. This warrants further investigation but perhaps reflects the fact that life has become more sedentary and unhealthy for succeeding generation.

2.4.4 Societies and Groups

There are several organizations and societies which are working to promote awareness of osteoporosis throughout the world. The UAE is about to set up it's own osteoporosis society which will probably be affiliated to the International Osteoporosis Foundation (Suhaili, 2005).

2.4.4.1 International Osteoporosis Foundation (IOF)

The IOF is an international, non-governmental organization. It began in 1987 as the European Foundation for Osteoporosis (EFO). There are 68 countries currently represented in the IOF through a committee of 128 National Societies. IOF's mission is to promote prevention, diagnosis and treatment of the disease worldwide (IOF, 2002). Countries in the Middle East which have member societies in the IOF are: Bahrain, Kuwait, Lebanon and Saudi Arabia.

2.4.4.2 Better Bone Belt, UAE

The Better Bone Belt (3B), which is also known as the National Osteoporosis Alliance is a local initiative that was launched in the UAE early in 2003. This is the first osteoporosis group to be formed in the country. The UAE's healthcare sector, governmental bodies and private-sector corporations are all represented in this organisation.

The group has begun a campaign which aims to alert the public and healthcare professionals about osteoporosis. To-date 3B has given various lectures and free bone density screening sessions in a variety of locations. The campaign plan includes: raising awareness of osteoporosis and bone health among people of all ages through various activities, promoting females at risk to take action by proactively assessing their risk and asking their physicians for advice, working with health care professionals to facilitate greater understanding of the disease and the distinct needs of people with osteoporosis, encouraging the UAE government's health departments to resource and deliver appropriate services to prevent and treat fractures, funding research in bone metabolism and related issues and working with private corporations to finance 3B activities.

2.4.4.3 The International Society for Clinical Densitometry (ISCD)

The ISCD aims to support high standards in the assessment of bone health and a large part of it's work includes continuing professional education and certification for clinicians and technologists. During the course of this research project, the author attended and achieved certification in bone density on both the physician and technologist ISCD courses, and also was accepted as a member of the ISCD teaching faculty for the Saudi Arabia Technologists programme. The information supplied by the ISCD helps professionals to maintain standards in bone strength measurements. It is planned that the 3rd Bone Density Course for the Arab world, following Jordan and Saudi Arabia, will be held in the UAE in 2007.

2.4.4.4 The Pan Arab Osteoporosis Society (PAOS)

The PAOS was established in April of 1997, during the first Lebanese International Meeting on Osteoporosis and included delegates from five countries: Lebanon, Egypt, Jordan, Tunisia and the United Arab Emirates. The principal objectives were to establish osteoporosis societies throughout the Arab World, and to promote awareness of osteoporosis among the general public and health professionals in the region. The PAOS also aimed to encourage research into osteoporosis and its prevention and, in particular, to establish BMD references for the populations of the Arab World. Since then the following countries have been added to the members: Syria (1997), Kuwait (1997), Oman (1997), Saudi Arabia (1998), Palestine (1998), Morocco (1999) and Bahrain (2000) and also recently Qatar and Libya joined. Often members officially establish societies and membership to the International Osteoporosis Foundation. At the recent PAOS meeting in Tunisia, Dr Suhaili of New Dubai Hospital in the UAE was announced to be their new President.

2.4.5 Education Programmes/ Interventions

2.4.5.1 Education of Young People

With the focus of interest centering more around education in order to improve peak bone mass and to encourage a healthy bone lifestyle, several groups have set up educational programmes aimed at the young. A group, from Creighton University Osteoporosis Research Center (Lypaczewski *et al*, 2002), has done just this with a free

educational programme for 9 year old girl scouts and their parents (mothers or other females). For two hours the girls rotated through 5 activity booths, each on a different bone related topic. This was a simple exercise in providing health information. It was analysed by completion of a pre and post test by the girls, in which they did better after the session than before, however it was not clear if the questions were the same which may have allowed them to remember what was required and get a falsely high result. Rechecking these girls after one year would have been beneficial to see if they followed the advice given.

The paper by Leslie and St. Pierre (1999) examined the risk factors for osteoporosis and ways of reducing risk in college students with intervention strategies. They suggest that the college setting allows for three key areas for osteoporosis prevention strategies to be employed; 1/ food service administrators should provide calcium rich foods in cafeterias and restaurants on campus, 2/ campus health clinics should work with local health agencies to offer smoking cessation programmes on campus and 3/ all women should receive counselling regarding risk factors for osteoporosis. These strategies would transfer well to UAE students.

Peterson *et al* (2000) describe a combined behavioural and dietary intervention in a university in the US. 80 premenopausal women, between 18 and 30, who had a low calcium intake (below 700mg/day) were included. As will be used in this study, a questionnaire was employed to estimate calcium intake. The measurement timings were baseline, 3 months and 6 months which seems rather too short for detecting any change in BMD over the least possible change detectable due to limitations inherent in repeating the scan. Without intervention their control participants apparently lost bone, a situation which was stopped with increased dietary calcium.

3. RISK FACTORS

3.1.1 Risk Factors and Lifestyle

As there are no signs of osteoporosis being present prior to fracture, another way must be found to discover people at most risk from the disease. Much work has been done over the past years in this area and now there is a wealth of information about possible risk factors for developing osteoporosis. By considering which risk factors are present, to what extent and in which combinations, decisions can be made about necessary treatment plans for prevention of the disease which may simply be a change in lifestyle. This same knowledge of risk factors can be used as things to avoid in childhood and puberty in order to ensure that optimal PBM is reached.

It cannot be taken for granted that risk factors known to cause osteoporosis in other ethnic groups have the same effect on the UAE population, therefore this project aimed to produce initial evidence of presence and association of risk factors to bone strength. The list of known risk factors for fracture is similar to the list of risk factors for osteoporosis and falls into two groups; some risks will be present and cannot be altered (non-modifiable) but others (modifiable) can be changed. Table 6 based on the NOF Physician's Guide, summarizes the risk factors for fracture.

Non-modifiable:

- **Personal history of fracture as an adult**
- **History of fracture in first-degree relative**
- Caucasian race (white or Eurasian ancestry)
- Advanced age (aged 50 or older)
- Female sex
- Dementia
- Poor health/frailty

Potentially modifiable:

- **Current cigarette smoking**
- **Low body weight (<58kgs), thin, small-boned**
- Estrogen deficiency:

  Post menopause

  Early menopause (<age 45) or bilateral ovariectomy

  Prolonged premenopausal amenorrhea (>6 months)
- Low calcium intake (lifelong)
- Limited exposure to sunlight or insufficient Vitamin D in the diet
- Alcohol (consistently more than two units a day)
- Caffeine (consistently more than three cups a day of coffee, tea, cola)
- Impaired eyesight despite adequate correction
- Recurrent falls
- Inadequate physical activity
- Poor health/frailty
- Excess use of certain medications (glucocorticoid)

Note that poor health and frailty, which may or may not be modifiable, appear under both headings. The four items in boldface—personal or family history of fracture, smoking, and low body weight—were demonstrated in a large, ongoing, prospective US Study to be key factors in determining the risk of hip fracture (independent of bone density).

Table 6 Modifiable and Non-modifiable Risk Factors for Fracture

This list is a fundamental part of this research since most of the risk factors shown will be tested in the project.

3.1.2 Non-Modifiable Risk Factors for Osteoporosis

The following sub-sections deal with each of the risk factors selected from the previous

table and explains how they link to osteoporosis.

3.1.2.1 History of Fracture in Self or Relative

This research project asks questions about previous fractures and whether or not they were caused by an unexpectedly low amount of trauma, because breaking a bone due to it's fragility rather than the normal amount of trauma is on it's own a clinical definition of osteoporosis. Also, having a first degree relative who has suffered an osteoporotic fracture doubles the individuals risk for osteoporosis (Cummings *et al*, 1995). Osteopaenia is the outcome under study, rather than osteoporosis, as the participants are young adults therefore family fracture history will not be questioned.

3.1.2.2 Ethnicity

Ethnic differences in BMD are well known. The National Osteoporosis Risk Assessment (NORA) study was of a large group of US ethnic minority women (18,000) and confirmed the low frequency of osteoporosis in African American women and the high incidence in Asian women. Another study by Mackelvie (2001) investigated a small number of Caucasian and Asian girls and found that Caucasian girls consumed an average 35% more calcium than Asian girls which may play a part in the differences seen between ethnic groups' BMD; Caucasian girls in this group had an average 9% higher BMD than Asian girls.

A group of researchers headed by endocrinologist and Professor Hussein Saadi at the Emirates University, Al Ain, UAE have recently been investigating UAE national women. Of the few papers published, one measured lifestyle factors in UAE national's compared to QUS of the calcaneum in 185 women, mean age 22 years (Saadi, 2001). The study used only the right calcaneus, which may have overestimated bone strength on occasion as it is preferable to measure the non-dominant heel to find the weakest area (dominance implies more use and therefore possibly greater strength). Physical activity was estimated by the answers to four questions and did not appear to address well enough the importance of load bearing exercise, nor the duration of the activity, which may account for the lack of correlation with bone strength results. In fact none of the questions asked specifically included exercises which are thought to increase bone density as shown in Table 7. The study concluded by stating that the estimated mean

from QUS measurement for the group was 0.56 g/cm^2 which they compared to a US Caucasian mean of 0.64 g/cm^2, as provided by Hologic in 1998. From this they assumed that on the Caucasian scale, 27% of their subjects had osteopaenia. The mean value for Caucasian women provided by Hologic today on their equipment, however, is 0.58 g/cm^2 which is much lower and closer to the stated female UAE mean. None of the participants smoked, which is not surprising as smoking amongst females in the Arabic or Muslim culture in the UAE is very much frowned upon and extremely rare. Mean dietary calcium intake, at 968 mg/day, was lower than the 1200mg required and it was stated that 24% of participants consumed less than 500 mg/day therefore it is interesting that no link was seen between BMD and calcium. This could be due to the lack of number of individuals with very high calcium intakes. There was a trend toward showing lower BMD than for the Caucasian group but not statistically significant (P=0.09). Late menarche and low body mass were the only independent predictors of QUS parameters.

The same group's second, larger, study was very similar to the first, again studying only National UAE women (Saadi, 2003). This time, pre and post menopausal women were included in the total of 411 women participants. The sampling was random of citizens in the Al Ain district. The physical activity questions were validated for the assessment of customary activity in old people, which was felt to be sufficient for all candidates because women in this culture very rarely perform sports. The participants were grouped as pre (n=330) or post menopause (n=81). The study did not find a correlation with calcium and QUS parameters in either group, but did correlate exercise only with the post menopausal group; perhaps because the tool was unable to identify exercise correctly for premenopausal women. Healthy young women in the study (n=171) between the ages of 20-29 years were compared as a group to other ethnic populations; BMD was significantly lower for the UAE group than US or European Caucasian and Asian groups. The mean healthy young women's BMD was 0.45 g/cm^2 which was much lower than the previous study discussed above. Age, BMI and physical activity were the best predictors of QUS parameters. As an addition to this study, vitamin D levels were checked on some subjects with osteopaenia. The preliminary data found that vitamin D deficiency in young healthy women may be present, possibly due to insufficient sunlight exposure.

In November 2004, Saadi *et al* published research which further addressed the issue of vitamin D status in UAE women. A small group of 56 women had QUS of the calcaneum and DXA of spine and hip in addition to a radioimmunoassay test for serum 25 hydroxyvitamin D (25 OHD) level. The QUS/DXA correlation between heel, spine and hip tests was found to be strong enough to continue advocating heel QUS as a method of identifying post menopausal women with low BMD. Of 21 premenopausal women with low BMD results (<-1 SD), 95% had 25 OHD levels < 50 nmol/l and 57% had levels < 30 nmol/l. The desirable level is more than 30.

To the researchers current knowledge, no research has been published which includes all Arab nationalities residing in the UAE, nor males. This project will be unique in including the aforementioned subjects.

Bererhi *et al* (1994) measured the BMD of 194 Omani women. When the BMDs of the Omani group were compared to BMDs of a similarly aged British group, BMDs in Omani women were found to be significantly lower. However, the two studies were not carried out with the same equipment – one using Dual Photon Absorptiometry (DPA) and the other DXA, which are slightly different pieces of equipment, as will be explained in chapter 2. This may have had a confounding effect on the results although Gluer *et al* (1990) found a 98% correlation between DPA and DXA, but highlighted the importance of further research being done in this field.

A study in Saudi, Ghannam *et al* (1999), looked at BMD, clinical and biochemical parameters in 321 healthy Saudi females. There were no reference ranges of BMD available for the population and the study aimed to address this. The study took into account the number of pregnancies (3.1+/- 3.1 pregnancies) and total duration of lactation (23.7 +/- 42.4 months) of the women, as multiple pregnancies are very common in this population. Prolonged lactation is thought to reduce bone density. Serum calcium, 25 hydroxyvitamin D (25 OHD) and parathyroid hormone (PTH) levels were also monitored. The results showed that BMD values in healthy Saudi females, compared to their USA counterparts, were significantly lower. Importantly, the study also showed that severe hypovitaminosis D was present in 52% of the subjects. Saudi females are almost always completely covered from head to foot and are thus unable to receive the sun exposure required to maintain adequate vitamin D

levels.

In Jordan (Shilbayeh, 2003), 402 women visiting out patient clinics at two hospitals in Amman over a two year period were evaluated clinically and with BMD tests of spine and hip. 30% of the cohort was identified as having osteoporosis, 44% osteopaenic and 26% normal. One of the variables which was noted as a significant risk factor for low BMD was smoking more than 25 cigarettes per day. Compared to the UAE where almost no women smoke, smoking amongst females in Jordan is prevalent. Since these women were not all healthy it is difficult to make conclusions about low BMD prevalence but the authors felt that the prevalence of osteoporosis was high in their opinion.

3.1.2.3 Gender

Female sex is a non-modifiable risk factor for osteoporosis, but men are also at risk to a lesser extent and must not be overlooked in research which is why this study is including males and females. It has been estimated that 40,000 symptomatic vertebral fractures occur in the UK each year of which 20% are in men, and 60,000 hip fractures of which 30% are in men (Eastell *et al*, 1998). Partly, the reason that females are more at risk for osteoporosis is the rapid decline in bone mass after menopause caused by the withdrawal of sex hormones. This is also a factor in males as rapid bone loss is seen after rare instances of castration (Stepan *et al*, 1989). Males suffer from osteoporosis as do females and for some time were largely overlooked in research. As men live longer than previously, they will have even more chances of reaching the age where osteoporosis appears. It was reported that men who sustain a hip fracture have a poorer prognosis than women (Diamond *et al*, 1997) in a study which evaluated outcomes prospectively at 6 and 12 months post fracture. The study found men to have more osteoporosis risk factors also.

3.1.2.4 Age

Age is the most important risk factor for predicting low BMD (Siris *et al*, 2001). Bone is lost with increasing age but in this study young healthy adults are the target therefore age is not a factor under investigation. From peak bone mass, involutional bone loss does not begin until the age of about 35 in both sexes. With increasing age calcium is less effectively absorbed, impacting on bone strength. Also, older people can be more

frail and prone to falls, increasing their likelihood of fracturing.

3.1.3 Modifiable Risk Factors for Osteoporosis

Smoking, alcohol or caffeine consumption, diet and exercise are termed lifestyle habits. Although our height and bone size will be determined genetically, lifestyle factors can influence development of peak bone mass. The National Osteoporosis Foundation (NOF, 2000) states that the general public could maximize and preserve bone mass by following guidelines regarding lifestyle, such as ensuring an adequate intake of calcium and vitamin D, regular weight bearing exercise, avoidance of both tobacco use and alcohol abuse.

This section will explore the view in current literature of modifiable risk factors for osteoporosis. All of these factors can be changed by the aware individual and are worthy of focus in any population to first assess the situation and then measure against known values for healthy bone achievement. Once shortfalls have been identified, a programme of education or even intervention can be considered. In the article on osteoporosis by Tuck and Francis (2002) the following, Figure 6, shows the rate of bone accrual/loss against age with management superimposed.

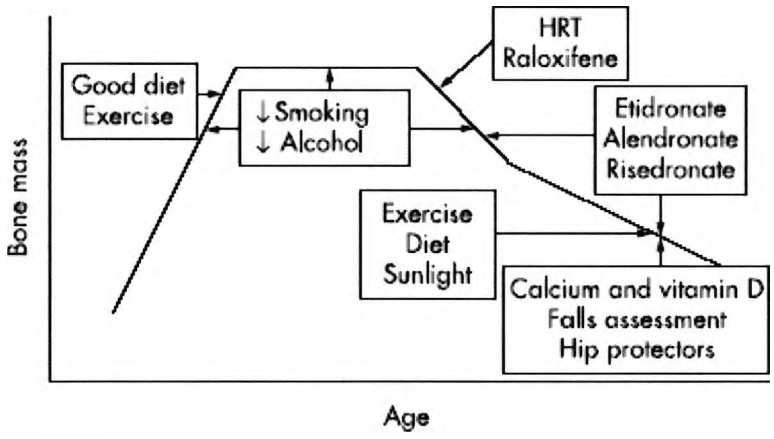


Figure 6 Schematic Representation of the Management of Osteoporosis

The diagram indicates that in youth the management of bone development should be controlled through diet and exercise. It is unclear whether the average Arab child in the UAE has been exercised enough or had an adequate calcium rich diet and future

research in this area is warranted.

3.1.3.1 Smoking

When the European Prospective Investigation of Cancer (EPIC) Norfolk study investigated heel QUS and exercise (Jakes *et al*, 2001), risk factors for osteoporosis were considered, one of which was smoking. In this large group of almost 5,000 participants it was found that the prediction of ultrasound attenuation from SOS was similar for smokers and former smokers which could suggest allowing a category of "ever smoked" to be used.

Elgan *et al* (2003) investigated 118 healthy young women some of whom smoked and/or used oral contraceptives. DXA BMD and lifestyle were measured. Smoking was associated with a lower BMD than non-smoking. The EPIC study produced another article discussing the effect of smoking on BMD in postmenopausal women (Grainge *et al*, 1998). 580 postmenopausal women were studied by questionnaire for smoking, and DXA for BMD. At ages 20, 30 and 40 years there were significantly lower BMD values for smokers compared to non-smokers. The research study in Sharjah will ask whether the participant does or has ever smoked.

3.1.3.2 Height, Weight and BMI

BMI is a factor most strongly associated with BMD as has been shown in numerous studies (van der Meulen 2000). BMI categories are underweight (<20 kg/m^2), normal (20 - 24.9 kg/m^2), overweight (25.0 - 29.9 kg/m^2) and obese (30.0 - 34.9 kg/m^2). Low BMI or underweight is an accepted risk factor for osteoporosis and in the study by Korpelainen *et al* (2003) the authors went as far as to suggest that the other known risk factors such as low physical activity only affected the underweight group whom they defined as less than or equal to 25.1 kg/m^2 however under classifications used in this research this includes underweight and normal weight (which is 20-25 kg/m^2).

It is continually being reported in the media that obesity is a big problem in America, and other nations are saying the same. Obesity, due in part to inactivity, is a major current health problem. Although an increased BMI would have a protective effect on the bones, the inactivity is a bone strength reducer, and the net effect is unclear.

3.1.3.3 Oestrogen Levels

Oestrogen levels are linked to BMD and this project will question age at menarche and menstrual regularity in order to correlate findings with BMD. Late onset of menarche, after age 17, and amenorrhea of over 6 months are risk factors for low bone density because oestrogen should be present in order for bones to develop fully. Later menarche has been described as being independently responsible for osteopaenia in UAE females (Saadi, 2001). However, Gerdham (2004) suggests age at menarche to have little or no importance as a risk factor when subjects reach old age.

3.1.3.4 Calcium and BMD

3.1.3.4.1 Daily Calcium Intake

It is generally agreed that an adequate intake of calcium is 1200 milligrammes per day (mg/d). Many studies have noted that calcium intakes are below this level (Cadogan 1997). The amount of calcium in the diet of young people is of concern. Studies have shown that minimum calcium requirements are not being met. Bonofiglio (1999) found in his study of 100 women aged 20-24 in Southern Italy that calcium levels were above the Recommended Daily Allowance (RDA) in only 31% of women. This statistic was based on morning, fasting, blood samples from which 25 hydroxycalciferol (25 OH-D) serum levels were measured. A fact sheet produced by the National Institute of Health NIH (1999) comments that it has been suggested that calcium deficiencies in the young can account for a 5-10% difference in peak bone mass and can significantly increase the risk for hip fracture in later life. In a further fact sheet, giving an overview of osteoporosis, the NIH (2000) reports that national nutrition surveys have shown that many people consume less than half the amount of calcium recommended to build and maintain healthy bones.

Calcium is found in the bones (99%), the cells and the blood. If the diet does not include an adequate calcium supply, calcium will be removed from the bones. With increasing age calcium is less effectively absorbed. Another factor regarding calcium is that a high fibre diet, whilst being a healthy option for many reasons, may be high in phytate, which inhibits calcium absorption (OSC, 2001). There are no side effects of consuming more than the recommended daily intake of calcium (OSC, 2001).

3.1.3.4.2 Calculation of Calcium Intake

There are several ways of attempting to calculate dietary calcium intake, each having advantages and disadvantages. The method of using a previous day food recall questionnaire is used in this research because of convenience. Asking participants to provide a three day food diary, another method, requires a large commitment from the study participants and extra costs to the project in terms of time for analysis and payment for specialized services of a nutritional expert. Added to that, there are no known lists of foods or validated methods of assessing the diet contents of Arabic food and to use a Western analysis could introduce error. Large studies such as National Health and Nutrition Examination Survey (NHANES III) (Mussolini, *et al*, 2001) used a 24 hour food recall method of assessing nutritional variables. Many other studies investigating bone density have used food frequency questionnaires based on the calcium content of food items (Mackelvie 2001).

3.1.3.4.3 Milk Intake

In order to investigate the effect of milk supplementation on bone mineral acquisition an intervention study was performed across 4 schools in Sheffield, UK (Cadogan, 1997). 82 healthy, white girls of an average of 12 years were included in the study. The intervention group was given 568mls of fresh milk per day for 18 months. Outcome measures included BMD measured by DXA, biochemical markers of bone turnover and hormones important to skeletal growth. At the start of the trial the daily milk intake averaged only 150mls. The study concluded that increased milk intake led to greater skeletal mineral acquisition although no change was noted in bone turnover markers. It was also mentioned, however, that milk contains other nutrients essential for bone health which may have added to the effect. Milk is an important provider of calcium in the diet and the level of consumption by UAE young adults is unknown.

3.1.3.5 Sunlight Exposure and Vitamin D

Vitamin D, crucial to calcium absorption, is usually obtained by exposure to the sun. Fifteen minutes per day of sun exposure to the hands and face will provide enough Vitamin D for good bone health (Osteoporosis Society of Canada, 2001, NOF, 2000). However, in the UAE there are some females who completely cover their skin for religious and cultural reasons. In this case, they may be at risk of vitamin D deficiency.

There is another source of vitamin D in the diet in the UAE which comes from fortified milk. Vitamin D increases calcium absorption. The recommended daily intake for vitamin D is 400-800 International Units (IU) or 10 to 20 μg per day. In the reported studies done in the UAE on National UAE women and other studies in Saudi Arabia it has been noted that low BMD could be due to inadequate vitamin D levels due to inadequate sun exposure. This project will question hours of sunlight received. To check vitamin D levels requires a measure of 25(OH)D serum levels and the results should show an optimal level of 50-150 nMol/L, less than 20 is deficient and 20-50 is insufficient (Ott, 2003). However, blood testing is not being included in this project for logistical reasons.

3.1.3.6 Alcohol

When the National Osteoporosis Risk Assessment (NORA) study, as written up in 2001 by Siris *et al,* described alcohol consumption it made the rather surprising comment that low alcohol use (1-6 drinks per week) was associated with a significantly decreased risk of fracture (Rho 0.85). Alcohol consumption is generally regarded as a risk factor for low BMD. In this Arabic community Muslims are not allowed to drink. To ask a question about alcohol consumption would not be appropriate and would likely cause offence and therefore has not been done in the lifestyle questionnaire. Sharjah does not permit sale or consumption of alcohol within the Emirate although other Emirates do allow it providing the person concerned holds a valid alcohol license. Not all Arabs are Muslim therefore it is possible that some of the participants consume alcohol however the number and amount is estimated to be very small and is not being assessed in this study.

3.1.3.7 Caffeine Consumption and BMD

Excess caffeine intake, Wyshak (2000), is thought to impair calcium absorption in the diet. This study will question the number of caffeine containing drinks per week in order to look for negative correlation with BMD.

In a review of nutrition relating to bone health by Ilich and Kerstetter (2003) it was suggested that caffeine negatively correlated with intestinal Ca absorption causing a more negative Ca balance. When caffeine is taken as a cup of coffee the addition of milk apparently offsets this effect however a can of cola does not have that advantage.

The review also concluded that caffeine is probably more harmful when calcium levels are inadequate. Vending machines are seen all around student campuses and observations suggest cola consumption could be high.

3.1.3.8 Effect of Exercise Level and Type on BMD

Exercise is vital for bone health and is a primary factor associated with BMD. In order for exercise to be beneficial to bones it must be weight-bearing. Physical stress increases bone mass while immobility leads to bone loss. Physical exercise also increases general health. The WHO commented that along with tobacco use and unhealthy diet, physical inactivity is recognized as a significant common and preventable risk factor for NCD. They estimate that over 60% of the world population is not physically active enough to gain health benefits (WHO, 2001).

According to the review by Todd and Robinson (2003), a German anatomist called Julius Wolff first wrote about the link found between body weight and bone size in 1892, but much earlier in 1683 Galileo had recorded an association between mechanical stress and bone mass. It is appropriate that exercise and bone mass has such a long history of documentation since it appears to remain one of the most important factors modifying bone mass to-date. Not only have numerous studies been completed using self reporting exercise questionnaires but many intervention studies have also been done. In Todd's review, it is stated that type of exercise is very important to successfully increasing bone mass, as is peak load of exercise rather than number of repetitions. In the conclusion of their review they provide the following details, shown in Table 7, of different forms of exercise and their impact on BMD as taken from all the articles researched.

Form of exercise	Impact on BMD	Sites
Swimming	None	–
Walking	Protects against further loss	Hip, lumbar spine
Gentle aerobic exercise (low impact)	Protects against further loss, may increase	Hip, lumbar spine
Vigorous aerobic exercise (high impact)	Increases	Hip, lumbar spine
Weight training	Increases	Hip, lumbar spine, radius
Running	Increases	Hip, lumbar spine
Squash	Increases	Hip, lumbar spine, racquet hand

Table 7 Different Forms of Exercise and their Impact on BMD

Table 8 is taken from Tuck's article on osteoporosis and was originally adapted from guidelines from the Royal College of Physicians. It describes exercise as being a Grade A (strongest) influence on hip fractures, calcium intake and smoking are graded as B with alcohol intake receiving a C grade.

	Bone density	Vertebral fractures	Hip fractures
Exercise	A	ND	B
Dietary calcium	B	B	B
↓ Smoking	B	B	B
↓ Alcohol	C	C	B

ND indicates that a beneficial effect on fracture incidence has not been demonstrated.

Table 8 Grading of Lifestyle According to their Effect on Fracture Prevention

Many studies have looked at the impact of exercise on bone for example those by Jakes (2001) and Weaver (2003)) and concluded that exercise in moderation increases BMD. Extreme levels of exercise can cause low BMD partly due to amenorrhea and subsequent oestrogen loss in females. The NHANES III results were used to assess jogging in men by Mussolini *et al* (2001). 4,254 men were included in the data analysis of which 954 jogged and 3,300 did not. Those who did not jog but exercised were further separated from those who reported no leisure activities, n = 577. The BMD measurement method was DXA of the total hip. Men who jogged more than 9 times per month had a statistically significant ($P<0.01$) increase in BMD over those who jogged 1-8 times per month. Joggers (even at moderate frequencies) had an almost 8% higher mean BMD than those who performed no leisure activities. This study only addressed one type of exercise – jogging, and frequency per month. Other aspects are important in exercise such as intensity of the exercise performed.

The EPIC study was designed to investigate major chronic diseases. Between 1993 and 1997 the Norfolk cohort of 25,633 men and women of ages 45 to 74 was recruited. As part of this study some participants (2,143 men and 2,631 women) had QUS of the calcaneus providing Speed of Sound (SOS) data and also completed a self reported physical activity questionnaire. Physical activity was analysed according to level of impact and time spent per week (Jakes *et al*, 2001). This study added to knowledge

regarding exercise and bone density by proving that participation in high impact (e.g. competitive running, jogging, tennis, football, netball) sport was independently associated with higher QUS attenuation at the heel, indicating higher BMD.

The focus for osteoporosis prevention has turned to adolescents and thus adolescent levels of exercise. In a study by Lloyd *et al* (2000), exercise and calcium intake were related to total body bone mineral gain and proximal femur bone mineral density. The objective was to study a group of girls longitudinally from 12 to 18 to see the effect of calcium intake and exercise levels on BMD. The subjects were part of a larger, continuing, prospective epidemiological study which began in 1990 in Penn State, US, called the Penn State Young Women's Health Study. The study results were based on a group of 81 white females of very similar ages (+/- 6 months of each other). BMD was recorded using Hologic pencil beam equipment and measured yearly. The research did not find any link between calcium intake (above the average daily intake of 919mg) and BMD, but did show that exercise was associated with increased hip BMD. Had this study included participants with lower calcium intakes, <500 mg/day, then a link may have been seen between increased calcium intake and increased BMD. The result of no association between BMD and calcium in this study is perhaps therefore misleading. The researchers noted that by engaging in some form of daily exercise as compared to a sedentary lifestyle, a change in bone density of $0.05g/cm^2$ was observed – enough to decrease osteoporotic fracture risk by 50% (Riggs, 1992).

College students were the target of research regarding exercise levels in a study of 332 first year American University students (Pinto and Cherico, 1998). The aim was to examine student participation in both vigorous and moderate exercise and compare it to national exercise goals as set by the Centers for Disease Control and Prevention (CDC), the American College of Sports Medicine and the surgeon general. The mean age of the students was 18.6 years and the mean body mass index was 21.7. Just over half of the group were women. Physical activity was self reported and based on how many times in a week each type of exercise level was performed. Although the study did not show any decrease in activity levels during the first year of university, it did highlight the fact that 42% at outset, and 36% at one year, of the group did not meet recommended exercise levels.

There is currently great concern at the alarmingly low rate of physical exercise in children and the parallel increase in cases of obesity. This situation is replicated in the UAE according to local experts and recent studies. At a recent function in Abu Dhabi to mark World Heart Day on 23rd September 2005, the head of the Emirates Cardiac Society (ECS) stressed the urgent need for a change in the lifestyle of UAE residents (Muslim, 2005). The president remarked on the unhealthy diet and sedentary lifestyle of many UAE residents. The ECS further commented that only 8% of Middle Eastern people eat vegetables and fruit regularly and only 4% regularly exercise. It was reported that 75% of women and 70% of males are overweight. The vice president of the society called for more awareness programmes and health education rather than waiting until the end stage which requires expensive treatment. Although this related to heart disease, the same principle holds for osteoporosis.

A study by Henry, Lightowler and Hourani published in 2004 investigated physical activity levels in adolescent girls in the UAE. 58 girls from 2 government schools filled in 3 day activity questionnaires. Physical activity was found to be very low which the authors considered to be due to hot weather and cultural attitudes inhibiting participation in sports or any kind of exertion. If this is indicative of all UAE adults then it is of great concern.

4. BONE STRENGTH MEASUREMENTS

4.1 General

The dependent factor to be measured during this research is bone strength and therefore it is necessary to consider the different ways that this parameter can be measured or investigated. Bone strength is measured and compared to a normal reference range in order to detect low bone strength or osteoporosis. Several different methods are available, and are described in the following sections. Currently, the best indicator of the strength of the bones is density. Bone density is referred to as bone mineral density (BMD) and is measured with specialized X-ray equipment. The unit of measurement is g/cm^3 (grammes per cubic centimeter) if measured in three dimensions. Most available equipment, however, only measures area and not volume therefore the unit is g/cm^2. By repeating bone mass measurements over time, changes can be recorded, for example to assess response to treatment. The value of BMD is that it predicts fracture risk.

Ultrasound is a method available for assessing the bones; a technique which measures bone quality but also can assess fracture risk. Both BMD and ultrasound measurements of bone were chosen as methods for this research project. The following sections give an overview of all methods available and then the reasoning behind the selections made.

4.2 Choice of Equipment

This research project was funded by a grant from the University of Sharjah research board. The terms of the grant do not allow for the purchase of capital equipment and the University does not have any bone strength measuring equipment. Therefore local companies were approached for the loan of QUS machines. The pilot study was completed with the generous loan of the Sahara ultrasonometer from Al Zahrawi Medical Company. The full study was accomplished through the kindness of both GE Medical who loaned the Achilles and City Pharmacy Company who loaned the IGEA DBM Sonic.

As stated, although 5 years ago there were no DXA machines in the local government

hospitals the situation changed in 2004 when the first machine was installed in Al Baraha Hospital in Dubai. The Head of the Ministry of Health for Dubai, the Technical Director and the Head of Radiology were extremely generous in making it possible for DXA scanning to be performed free of charge. Finally, thanks are due to H.H. Sheikh Mohammed, Head of Ministry of Health Sharjah and the Head Radiologist for allowing subsidized MRI scans to be done on a limited number of cases, paid for by the grant awarded for this research by the UOS.

4.3 Alternative Measurement Methods

Three bone measurement techniques were employed for the purpose of this research study, QUS, DXA and MRI. These three techniques will be explained in their own sections with justification for their selection but first the other imaging modalities will be introduced including their relevance in imaging today.

4.3.1 Radiogrammetry and X-ray

Using plain X-rays, although done in the past, is not a very sensitive way to show decreased bone loss and can only reveal severe osteopaenia. At least 40% of bone will have been lost by the time demineralization can be visually identified on plain films (Bonnick, 2004, p1). Alternatively, X-rays will show fractures which may lead ultimately to a diagnosis of osteoporosis. The technique of using X-rays for bone density has been used for the spine or hand. Early methods for the spine relied on looking at the trabecular pattern of the vertebral bodies, the more pronounced the vertical trabeculae were, the more bone had been lost (Bonnick, 2004, p2). The technique of estimating bone density from measurements taken from a radiograph of the hand is called radiogrammetry and is still available today as a computerized analysis of digitized images. A hand radiograph gives a dose to the individual concerned of approximately 50 μSv but another technique described below gives a much lower dose. Dose is an important consideration in technique selection because the stochastic effects of a possible long-term event such as leukaemia occurring after any X-ray procedure. Even the smallest dose of radiation cannot be ignored.

4.3.2 Radiographic Absorptiometry

Radiographic Absorptiometry (RA) is a technique using a computer generated or digital X-ray with a metal wedge in the field of view. A regular X-ray image is used which gives the subject a higher dose than the current recommended method of BMD measurement, DXA, approximately twenty times higher. The benefit is that specialized equipment is not required for acquiring the image, therefore the technique may still be chosen by some centers.

4.3.3 Quantitative Computed Tomography

Quantitative Computed Tomography (QCT) measures trabecular and cortical bone density at several sites in the body, but is most commonly used to measure trabecular bone density in the spine (NOF, 2000). Apart from the spine, this technique has also been used to measure the forearm with a smaller, dedicated scanner and is then termed peripheral pQCT (Langton, 2000).

A regular CT scanner can be used for QCT. Bone mineral measurements are calculated and compared with reference material. Bone mineral density is directly calculated in 3 dimensions. Only this technique can distinguish between cortical and cancellous bone; a great advantage as inclusion of cortical bone in the measurement area for cancellous bone would falsely increase the measurement. However, the disadvantages are the limited availability of QCT due to either lack of software or lack of scanning time on a busy machine. It is also a relatively high exposure to ionizing radiation, and of relatively high cost. These considerations rule it out as a screening tool or research method for healthy young adults (AMA, 1999: 8). It would be highly unlikely that ethical approval would be granted for this method to be used on young, healthy individuals. The radiation dose for QCT is about the same as a chest X-ray at between 50 – 60 μSv.

Although the gold standard method of bone strength measurement is DXA, it is not portable and so research volunteers have to be transported to it. QUS is the second most popular method of assessing bone status and it is non-ionizing and portable. This research uses QUS for all volunteers and DXA on those participants who agree to have it. The next sections discuss these methods in detail.

4.4 Quantitative Ultrasound

4.4.1 General

Ultrasound plays an important role in general medical imaging and also supplies bone strength measurement techniques, although generally without acquiring an image.

4.4.2 Ultrasound Propagation in Tissues

Ultrasound is a mechanical wave which can only travel through a medium unlike an electromagnetic radiation such as X-ray which can travel through a vacuum. Sound needs a medium to travel through because it propagates by a series of collisions between molecules in the tissues. The closer together the molecules are packed, the more effectively the sound can travel. Therefore a measure of the speed of sound in bone tissue reflects something about that bone tissue; it is of higher quality, more dense, the faster sound can travel through it. The ability of a bone to resist fracture depends on its elastic modulus or Young's modulus E, which is a factor of density and quality. It is calculated by measuring stress (force applied to a material) over strain (change in shape of the material) and reflects the bones ability to return to its original shape after an applied force has been removed, or elasticity. DXA, it should be noted, only measures density.

4.4.3 Ultrasound Principles of Operation

Quantitative Ultrasound (QUS) is the name for a commercially available method of passing high frequency sound waves through bone. The frequency of sound is a measure of the rate of repetition of the molecule disturbances. Audible sound frequencies range between 20 and 20,000 Hertz (Hz). Ultrasound as a term denotes sound frequencies above 20 kHz and medical ultrasound is usually in the range 1 to 15 MHz. Bone strength measurement uses ultrasound with a frequency of between 0.5 and 1.25 MHz.

QUS works by measuring either how quickly sound travels (its speed or velocity), or how much sound is absorbed by the medium, broadband ultrasound attenuation (BUA).

The values recorded reflect the quality of the bone being measured. The higher the quality, the faster sound will travel through it. Denser tissue causes more attenuation of the sounds waves and a higher BUA value. The unit of measurement is metres per second (m s^{-1}) for the speed of sound (SOS) or decibels per mega Hertz (dB MHz^{-1}) for sound absorption. The speed of sound through air is 300 ms^{-1}, through water 1,480 ms^{-1} and through the trabecular bone approximately 1,520 ms^{-1}.

4.4.4 Ultrasound Machines

The sites for measurement with QUS include the wrist, heel (calcaneum), tibia and recently the finger (phalanx). The advantage of QUS is that the equipment is cheaper, and smaller (allowing it to be portable). It is of great use for mass screening. The disadvantage is that the results do not correlate well with DXA measurements but this is because they are measuring different characteristics. A person with a low DXA result may have a normal QUS result and vice versa. Another disadvantage is that for technical reasons QUS cannot be performed on the anatomical sites of the spine and hip which are most at risk of fracture. However, it is thought to be a good predictor of fracture risk (Bauer *et al*, 1997) as will be discussed in more detail later. QUS does not use ionizing radiation. QUS and DXA will be compared in a further section.

A further point of note regarding QUS machines is that since sound does not travel well across air gaps, a method of bridging the gap between the place where the sound is emitted from the machine (transducer) and the skin surface must be found. In older systems, this was achieved by immersing the foot in a water bath but current systems use a coupling gel applied to the skin and transducer and are termed dry systems.

Positioning for these devices is crucial because if the calcaneum is even slightly angled across the line between the transducers it can have en effect on the measurements. Each company provides positioning aids for their equipment.

4.4.5 Hologic Sahara Bone Ultrasonometer

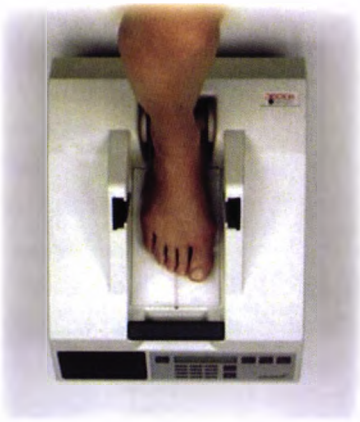


Figure 7 Sahara Clinical Bone Sonometer

Seen in Figure 7 is the Sahara; a small, light (10kg) QUS system. There are two fixed position transducers, one to emit and one to receive the ultrasound signal, which the heel is inserted between for measuring to take place. The transducers are encased in cylindrical pads which move horizontally inwards to make contact on both sides of the heel and then out again to allow ease of movement of the foot whilst positioning. The space between the 2nd and 3rd toes must be lined up with the mark on the bed of the device in order to correctly align the heel. The shin rests behind a support attached to the device which indicates the correct leg angle.

The Sahara determines the speed of sound by measuring automatically the width of the heel and the time taken for the signal to pass through the heel as shown in Figure 8.

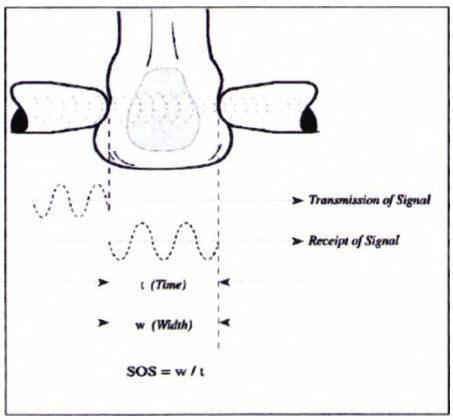


Figure 8 Speed of Sound Measurement

BUA is the average attenuation of sound across a range of frequencies, 0.2-0.6 MHz. It is measured at the same time as SOS. In order to account for any loss of sound caused

by the system itself, a phantom is measured first which has been factory calibrated. This is not done every time but at the start and perhaps end of a scanning session. The phantom is supplied with the unit.

Sahara measurements are completed very quickly, in less than 10 seconds. The coupling gel used is specially designed and must be the correct type. Sahara gel must be used, not water or oil based commercially available ones. Care must be taken that fibres or lint from tissues does not contaminate the transducers as this could affect the results, only lint free wipes should be used. The results are available immediately on the incorporated screen and can then be printed out on thermal roll paper.

Hologic offers two more results from a scan. The BUA and SOS are combined into the parameter called Quantitative Ultrasound Index (QUI) or sometimes known as stiffness. This combination has a better correlation to BMD than the single values alone. Hologic goes one step further and also gives an estimated BMD.

4.4.6 GE Achilles Express Bone Ultrasonometer

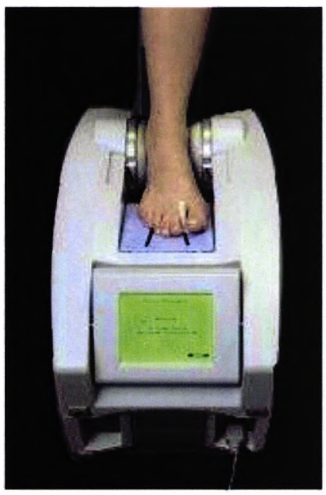


Figure 9 Achilles Express Ultrasonometer

Figure 9 shows the Achilles Express which is also small and weighs the same as the previous machine at 10 kg. Two transducers are used, one to emit and one to receive the signal. Two large, round rubber membranes (one on each side of the foot) fill with water during measurement so that they touch both sides of the foot. This allows the ultrasound signal to travel through water as it did in the older systems but without the foot getting wet. A toe peg is moved down between the 1st and 2nd toes in order to

correctly align the foot which is angled internally. The calf rests on a supporting device attached to the machine. The SOS through the heel is compared to the SOS through water alone. The transit time is counted as the time elapsed between the beginning of the transmitted pulse and the beginning of the received pulse as can be seen in Figure 10.

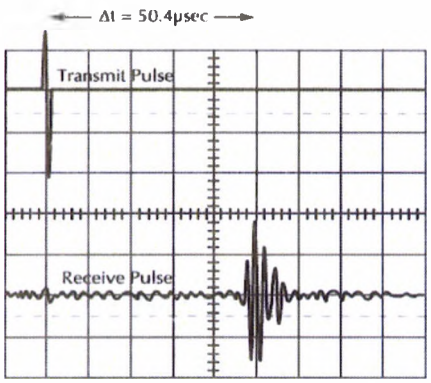


Figure 10 Measurement of Transit Time

BUA is the sum of the total attenuation across a range of frequencies after the attenuation from water alone has been subtracted. To carry out the initial measurements in water, a plastic device is inserted between the membranes for water only readings to be taken. These are compared in the machines electronic system to factory set normal values as a method of quality assurance prior to commencing a scanning session. As well as providing SOS and BUA, the Achilles also combines these two readings into a stiffness value called the stiffness index (SI). This is helpful because the BUA and SOS readings will vary in opposite directions according to variations in the temperature of the heel or water. The dependence of calcaneal ultrasound measurements on temperature was recorded by Nicholsen (2002) as a decrease in velocity of -2.2 m/s per degree C and a BUA increase of 0.75 dB/MHz. By combining them, the variations are cancelled out enabling faster measurements and a decreased precision error. The actual methodology as described in the operator's manual is Stiffness Index = (0.67 x BUA + 0.28 x SOS) – 420.

4.4.7 IGEA DBM Sonic Bone Profiler

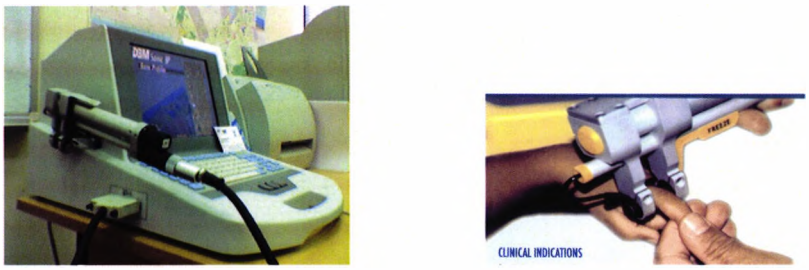


Figure 11 DBM Sonic Bone Profiler

This equipment is small and reasonably light, weighing 14 kg. It consists of a computer and a caliper which holds the two ultrasound transducers. The caliper is sprung so that it grips fairly tightly on the area being measured; important because the caliper will determine the distance between the transducers for calculating SOS. Measurements must be taken for the distal metaphysis of the first phalanx of the second, third, fourth and fifth fingers in sequence.

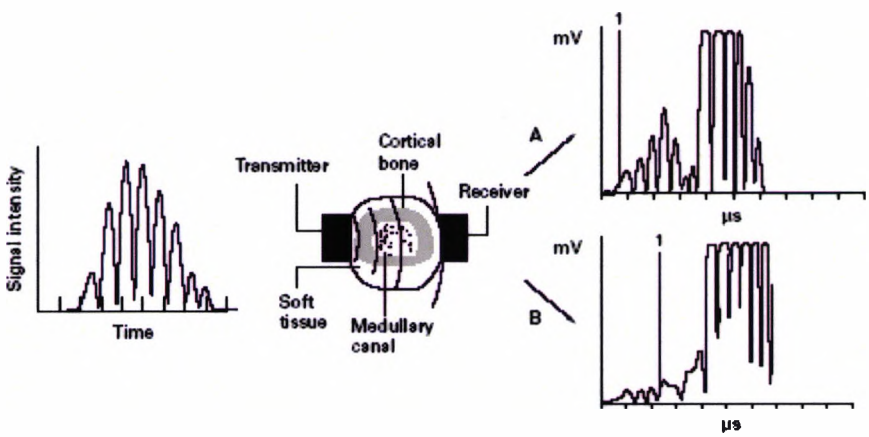


Figure 12 Diagram of DBM Sonic Operation Principles

A water based coupling gel is used on each transducer face. Figure 12 (Röben 2001) demonstrates on the left a normal graph of the increasing and decreasing signal strength emitted from the first transducer. The middle diagram shows the transducer positions either side of the phalanx and the diagram on the right shows a normal trace beside A and beside B a trace of a degeneratively diseased patient acquired by the receiving transducer. SOS is measured and is dependent on the amplitude of the receiving signal reaching a predetermined level of 2 mV, hence the measurement is called amplitude dependent SOS (AD-SOS). The transmitted frequency is 1.2 MHz. The SOS is

calculated by the time taken between emitting and receiving the pulse divided by the distance between the calipers.

Compared to the other two methods of measuring calcaneal QUS, this machine requires the operator to be properly trained and experienced. Placing the transducers either side of the distal metaphysis must be done with care, they must be aligned in the horizontal plane and also perpendicular to the axis of the phalanx. Deviation from this alignment would cause an incorrect measurement. Whilst the caliper is in position, the operator can have a small degree of freedom in angling the machine to try to obtain the best trace, which can be seen on the monitor. The traces are recorded repeatedly on automatic mode until sufficient numbers have been stored and then an average result is given. All the SOS values for the four fingers are then averaged to give the final result. Because of the length of time to acquire sufficient traces for one finger and the fact that this procedure is repeated three more times with re-application of gel, this technique takes considerably more time than the previous two QUS machines to obtain results.

The machine also provides other results at the same time. A measure of attenuation is given as AD-SOS and also a combined result known as ultrasound bone profile index (UBPI).

There is a problem of underestimation of SOS in large subjects because the thickness of the soft tissues falsely elevates the distance between the probes which then do not accurately reflect the bone width.

4.5 Dual Energy X-ray Absorptiometry

4.5.1 General

One of the original ways of investigating bone strength was to measure bone mineral density and this technique began with a dedicated single-photon absorptiometry (SPA) machine for the forearm in 1960 which measured photon attenuation. When photons are passed through a structure, more attenuation will occur the denser the structure through which the photons pass. Bone is a very dense tissue and attenuates the photons efficiently compared to soft tissue.

By measuring the beam intensity with a scintillation detector, after it had passed through the area of interest, and subtracting this from the initial beam intensity, the amount of mineral encountered could be quantified from the overall reduction in beam intensity. The results of multiple scan passes across a site, which was predominantly bone rather than soft tissue (such as the mid-radius), were calculated. This photon absorption result was then compared to the known attenuation from a calibrated standard phantom of human ashed bone in order to determine the amount of bone mineral present (Bonnick, 2004, p9). A condition of this process was that the surrounding soft tissue thickness was uniform which was achieved by using a water bath in some cases.

Because X-rays could only show changes due to bone loss on an X-ray image when considerable loss had occurred, this new technique, with low radiation dose, was successfully accepted into practice (South J, 2001). Early SPA used isotopes to provide gamma radiation for the photon production but this was changed to small X-ray tubes in subsequent machines. Machines using isotope sources had to be continually calibrated for the ongoing radioactive decay of the material, and would eventually require source replacement.

When the radioactive source is changed to X-rays, the technique is called Single Energy X-ray Absorptiometry (SXA). It also relies on X-ray absorption by bone but as it also cannot easily take into account soft tissue thickness in the field of view, it is therefore limited to peripheral sites (AMA, 2000). The SXA equipment available today measures either the calcaneum or phalanges. This technique, with its very low radiation dose and portability, would have been an option for this study except that it was not available in the country.

4.5.2 X-ray Interactions with Tissues

If the energy of a photon beam is just above the binding energy of the k-shell electron in the tissue through which it is passing then the transmission of photons drops dramatically and maximum attenuation occurs. This is desirable when using the attenuation of the beam to quantify the amount of bone in it's path. By adding another

beam of photons, this time with an energy level just above the k-shell electron binding energy of soft tissue, the attenuation due to soft tissue can be quantified and mathematically subtracted. In the same way as for SXA, the remaining intensity reduction due to bone alone was compared to ashed standards. The method of determining soft tissue discrete from bone allowed quantification of bone density in all areas regardless of the large or irregular soft tissues surrounding them. DXA soon became the gold standard for bone measurement.

4.5.3 DXA Principles of Operation

To produce two photon energies just above the k-shell binding energies of bone and soft tissue, the normal heterogenous X-ray beam must be controlled or modified. One company does this by using rare earth K-edge filters and another by using a pulsed power source to the X-ray tube. This research project used a Hologic machine which produces two alternating X-ray power sources at 70 and 140 keV (Bonnick, 2004, p14).

DXA is the measurement of the transmission through the body of these two different photon energy level X-rays. The attenuation coefficient of the material in question depends on its atomic number and also on the photon energies of the X-rays used. By measuring the transmission factors at 2 energy levels, the area densities or the mass per unit of projected area, of bone mineral (hydroxyapatite) and soft tissue can be inferred.

4.5.4 DXA Techniques

The sites chosen for measuring in the clinical setting are those considered most likely to fracture, the spine and hip. Lumbar vertebrae 1-4 are chosen for the spine. Figures 13 and 14 are examples of images of the scans for each area. In young research volunteers it was decided to opt for just one scan and the total hip was chosen because it is thought to best represent the individuals global BMD. In general, for diagnosis of low BMD, the total hip DXA reading is thought to be the most reliable as advised by the International Osteoporosis Foundation Committee of Scientific Advisors (Kanis and Gluer, 2000). The total hip measurement will be the DXA scan used for this study.

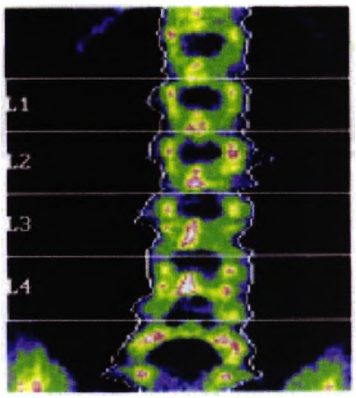


Figure 13 Image of a Spine BMD Scan

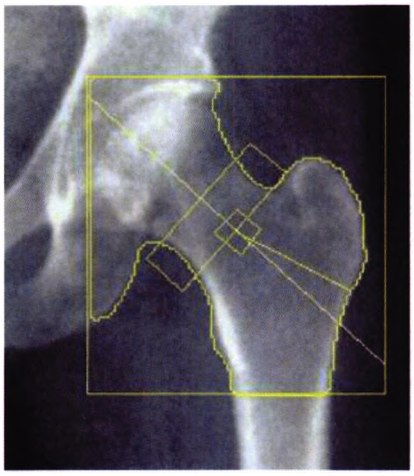


Figure 14 Image of a Hip BMD Scan

DXA is able to take quite clear images compared to the earlier resolution that was available on the first machines, although the images are not suitable for diagnosis. The X-ray tube is under the scanning couch and the patient is positioned supine so the image orientation is posterior-anterior (PA). The scan is taken line by line as the X-ray beam is highly collimated to a small area. The first line is at the caudal end of the scan working towards the head. The whole process is extremely fast. Because the image can be seen during acquisition, the software allows for repositioning during the scan. As soon as a few lines have been completed the operator can determine if the scan is correctly positioned. If it is not the scan is paused, readjustments made and the scanner software will restart the scan in the new position. This removes the need for repeat scanning and lowers the patient dose.

After the image has been acquired, usually this takes less than one minute, regions of

interest will be positioned onto the image. These regions are standard and the information gained will be compared with reference material therefore they must conform to a particular scanning protocol. On a hip scan four regions of interest are available which are: 1/ total hip, 2/ femoral neck, 3/ trochanter and 4/ inter-trochanteric regions. The total hip area is the most reproducible and therefore reliable area to use. The regions are first automatically placed by the computer and then manually checked and adjusted by an experienced technologist.

Quality Control (QC) on the scanner is performed daily and in fact the system will not operate until a satisfactory QC scan has been completed and stored. The QC scan is of a spine phantom made of calcium hydroxyapatite mounted in an epoxy material which simulates water shown in Figure 15. The result is compared to 10 separate measurements taken at the time of the system installation to check calibration and is also plotted on a graph to check for system drift (a gradual increase or decrease in values) which would indicate a fault. The DXA system also includes continuous calibration during scanning using a disc which is permanently installed inside the unit acting as an internal reference which compensates for beam variation from the X-ray source (Hologic Users Guide). This disc is made of known amounts of bone and soft tissue equivalent materials.

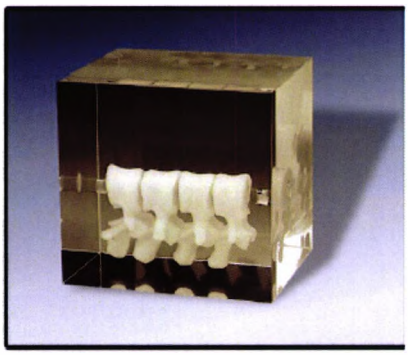


Figure 15 Anthropometric Spine Phantom

4.5.5 Hologic Delphi SL DXA Bone Densitometer

DXA equipment consists of an under the table X-ray tube linked by an arm to the detection system. There is a scanning table and an associated computer also, similar to those shown in Figure 16. The Hologic Delphi is a fan beam scanner. This means the X-ray beam is broad and associated with a fan of detectors so that an entire line of scan information can be collected simultaneously as indicated in Figure 17. Scan times are

extremely short at less than 1 minute because of this technique.

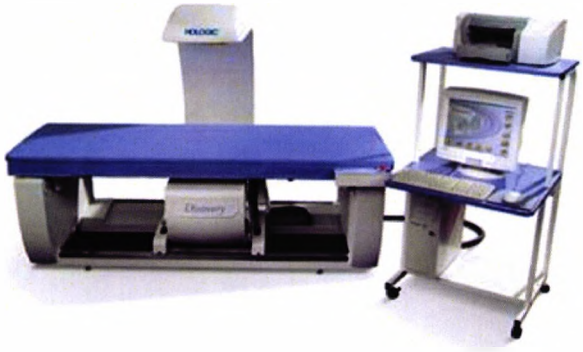


Figure 16 Hologic DXA System

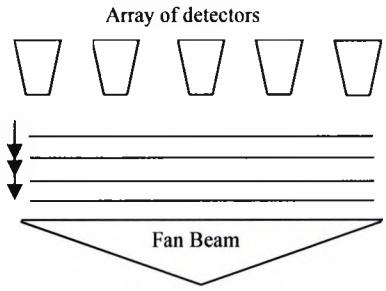


Figure 17 Diagram of Fan Beam and Detectors

To perform a hip examination the person lies supine on the scanning couch (Figure 18). Light clothing does not need to be removed which makes the procedure less daunting for healthy volunteers, however as well as metal, thick elastic could appear as artifact and should be excluded from the scanning area. There has not been any statistical difference found between the dominant or non-dominant hip on previous studies therefore the left hip was scanned as long as there was no history of injury or deformity. The left hip was nearest to the operator with the configuration of the Al Baraha scanning room. Positioning consisted of slight internal rotation of the left leg, which was secured in an immobilization device, ensuring that the hip is as straight as possible and the femur parallel with the long axis of the table. The centreing point, to align the laser cross-hair, is 4.5cms below the greater trochanter and 2.5cms medial to the shaft of the femur.

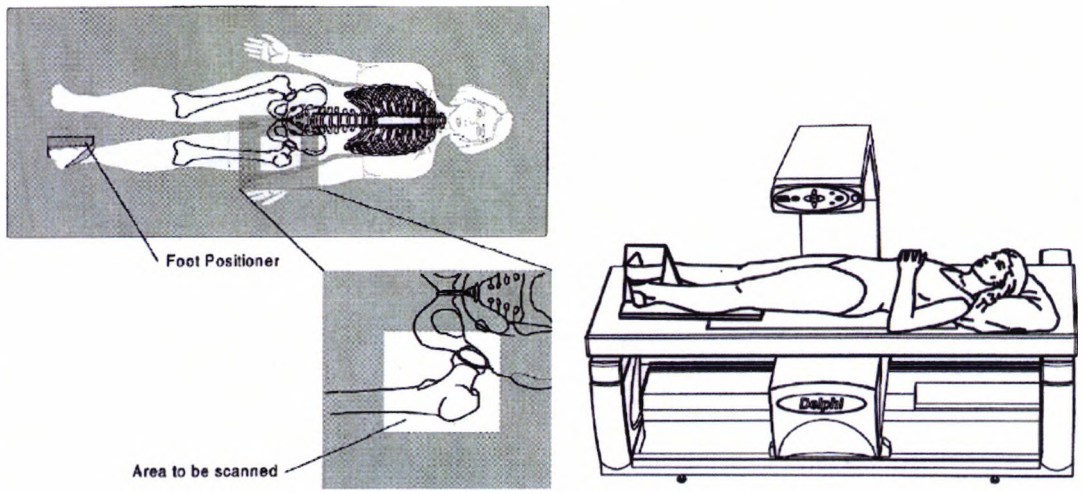


Figure 18 Positioning for Hip Scan

There are four scan types available on the Delphi, the one selected for use was the Fast Array mode. The scan time is around 30 seconds depending on the length of the image. The maximum default set for the hip scan is 15cm but the scan can be terminated before reaching this length if all anatomical detail has been included. A scan must include the greater trochanter centred vertically, the entire femoral head and several lines of scan below the lower border of the lesser trochanter.

After completing the scan, analysis is performed. An automatic analysis is performed by the system which the operator then views. The operator then checks for correct positioning of the regions and that all bone has been correctly identified and included. Sometimes the operator will need to redraw bone borders to add bone area where it has been excluded in error. First the global area of interest is checked to see that it includes: 1/ the whole of the proximal femure, 2/ the lesser trochanter, 3/ the top of the femoral head and 4/ the lateral side of the greater trochanter. Next the bone map is checked to ensure all bone has been included as bone can be added in but also bone can be deleted here if there is not enough room to position the neck box. Finally the neck box is positioned with the upper outer corner at the notch of the greater trochanter and the other three corners in soft tissue. Upon completion of analysis the results are displayed as area, bone mineral content and bone mineral density for each of four regions; the femoral neck, trochanter, inter-trochanter and total hip as shown in Figure 19.

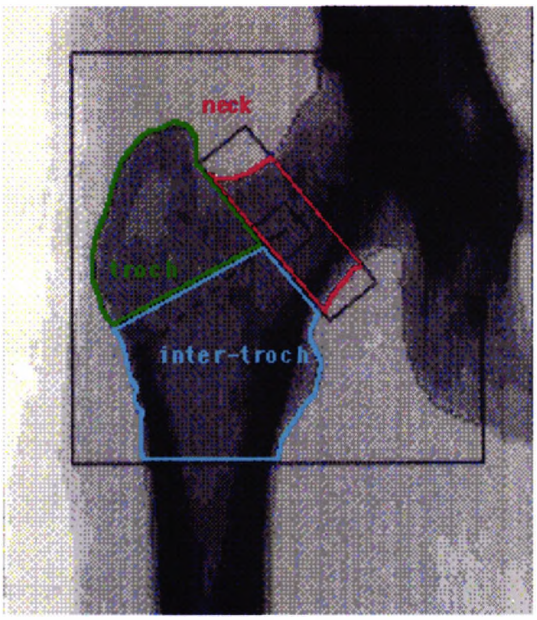


Figure 19 Hip DXA Regions

The measurements acquired in this way are two dimensional. In order to convert them to three dimensions, for the neck area only, the formula for a cylinder is applied. On Hologic equipment the height of the neck box is always 1.5cm therefore from the area presented on the report, the neck width can be calculated and then the volume so that using the BMC result the volume density vBMD can be found. This was done and is reported in the results.

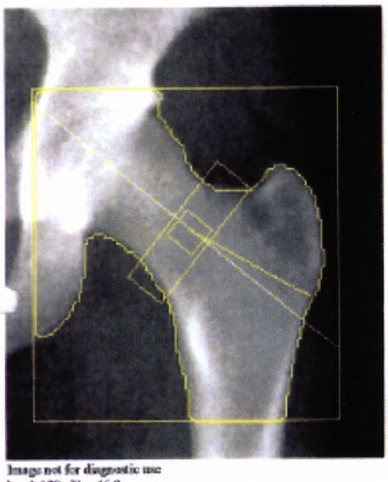


Image not for diagnostic use
k = 1.129, dl = 46.8
103 x 131

Scan Information:

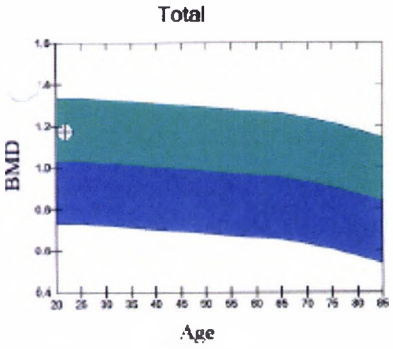
Scan Date: 18 April 2005 ID: A04180505
Scan Type: f Left Hip
Analysis: 18 April 2005 13:06 Version 11.2:3
Left Hip
Operator:
Model: Delphi SL (S/N 71011)
Comment:

DXA Results Summary:

Region	Area (cm^2)	BMC (g)	BMD (g/cm^2)	T - Score	Z - Score
Neck	5.76	5.58	0.968	0.3	0.3
Troch	11.48	10.39	0.905	1.0	1.0
Inter	19.19	26.81	1.397	1.1	1.1
Total	36.44	42.78	1.174	0.9	0.9
Ward's	1.30	1.37	1.05%	1.9	1.9

Total BMD CV 1.0%, ACF = 1.028, BCF = 0.993, TH = 6.85)

WHO Classification: Normal
Fracture Risk: Not Increased



Reference curve and scores matched to White Male

Source: NHANES

Physician's Comment:

HOLOGIC

Figure 20 Hip DXA Result Form

In Al Baraha Hospital the results page has been set up with different default graph presentation properties than the option shown later in this section, Figure 21, for the spine. The graph in Figure 20 shows two colours which are light blue and dark blue. The light blue indicates all results up to 2 SDs above normal and the dark blue region is for results up to -2 SDs below the average normal values according to age matched references. This result sheet is for a male. The reference data is from the NHANES study. A different graph is available for females.

4.6 Bone Measurement Technique Selection

Many methods of bone measurement are available and the relative merits of each are discussed in the following section. MRI was too new to be mentioned in this discussion as it is still at the prototype stage in clinical testing although small studies have shown it to be promising.

4.6.1 Comparison of Techniques

In 1997 Grampp *et al* presented comparisons of different non-invasive bone mineral measurements which were all done, for the first time, on one set of patients. The study was comprehensive including three categories of women, healthy pre and post menopausal and osteoporotic. Four types of BMD assessment were employed which were 1/ (peripheral) pQCT of radius and QCT spine, 2/ hip, spine and radius DXA, 3/ QUS of the calcaneum and 4/ RA of metacarpal and phalanges. The number of participants in each group was not large (around 40) and therefore the statistical power of the results may be in question. The results showed that in the two groups of healthy women all testing methods except pQCT correlated with age, with the highest correlation for QCT at the spine.

Steiger *et al* (1990) also reported on the ability of QCT to distinguish effectively between healthy pre and post menopausal women. This apparent superiority of QCT is understandable because all methods aim to measure sites high in trabecular bone which suffers much higher rates of bone loss than cortical bone. Only QCT is successful at imaging just trabecular bone and it performs a volumetric measurement compared to an areal measure for DXA.

The smallest correlation to age was found with QUS and this could be accounted for by the difficulty of this technique in repeating measurements with accuracy i.e. lower precision. QUS has the lowest precision of all the techniques. Importantly, all techniques except pQCT were found to be able to differentiate between the pre and post menopause groups and showed age and menopause related bone loss. After QCT, lateral DXA of the spine was best able to differentiate between groups. Again, this technique is better than postero-antero DXA imaging of the lumbar spine because there

is no superimposition of the retro vertebral body cortical bone structures, so the view more closely represents an area of trabecular bone.

Although the study showed that all techniques are able to determine bone loss, there was not agreement between methods on an individual basis, thus different techniques or different sites of the body labeled different patients as normal or osteopaenic, highlighting the need for follow-up to be anatomical site and equipment specific.

The results for DXA can be shown both in g/cm^2 and as a T-score, which shows the result as compared to a normal reference range for young adults. The categories are, as described by the WHO, +1 to -1 SD from the mean is normal, <-1 to -2.4 is osteopaenia and <-2.5 osteoporosis. The results for QUS are more difficult to assess as categories have not been formally identified or accepted yet. Some studies show that the same classification could be used whereas others indicate a different classification (Faulkner, 1999). For this study the classification will be described in terms of risk the same as for DXA, based on T-scores.

4.6.2 Correlation Between QUS and DXA.

In 2001, a study by Karlsson *et al* demonstrated that although the correlation may be imperfect between the estimated BMD of QUS and the BMD of DXA on the same subject, QUS could determine individuals by age, gender and fracture status even when their BMD values were the same. This suggested that QUS may give additional information to DXA, perhaps related to elasticity or connectivity of bone. Frost *et al*, (2001), surveyed over 1,000 women and found that QUS (Sahara) and BMD DXA of spine and hip gave similar bone strength results for women with up to four risk factors for low BMD. The proportion of women classified into osteopaenic and osteoporotic categories was similar with each method. Adler, 2001 found that in 185 men who had Sahara QUS of the heel and BMD DXA of the spine and hip, that the correlation between QUI of the heel and DXA of the total hip was 0.483 ($p_\alpha = 0.001$).

In a study of 185 men between 25 and 85 years old (Adler, 2001) who had been referred for DXA but consented to QUS also, it was found that QUS was not sensitive or specific in determining osteoporosis as defined by the corresponding DXA score.

The article suggested, though, that risk factors plus QUS could improve the situation.

4.7 Contraindications to Bone Measurements

Bone density measurement with DXA is suitable for almost all people without contraindications. Contraindications, some temporary, can be seen listed in Table 9.

Pregnancy	Increased abdomen thickness requires increased radiation dose
Oral Contrast Media	Recent administration will cause artifacts on the scan
Radio isotopes	Recent administration will cause background radiation
Orthopaedic hardware	Will be visible on the scan (for example hip prosthesis)
Metallic objects	Belts, buckles, zips, coins in pockets will cause artefacts
Calcium tablets	Ingestion of calcium containing tablets will effect the scan
Osteomalacia	Will cause under estimation of BMD
Osteoarthritis	Will cause over estimation of BMD
Previous fracture	Over estimation of BMD due to healed fracture site
Severe scoliosis	Difficult to image due to position of spine
Small stature	Not enough soft tissue for machine to determine bone area
Obesity	Unclear image, difficult for beam to penetrate

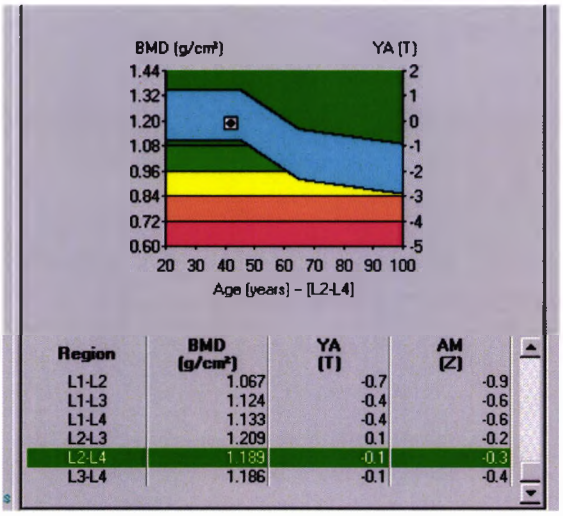
Table 9 Contraindications for DXA Scanning

There are few contraindications for QUS scanning. Oedema can cause a false reading as can abnormal foot temperatures. Foot deformity due to old injury, or congenital causes, preclude the use of the scanner which has fixed transducer positions. Open wounds are a contraindication to scanning because of the need to apply ultrasound gel as a coupling agent between the transducers and the skin.

4.8 Interpretation of Results

It must be remembered that BMD values for an individual from any method can vary depending on the equipment used and are not absolute. Therefore, the machine itself will be programmed with normal reference data, gathered by the company, for comparison of results. Two sets of reference data are used. The first is the expected BMD for a normal young adult (YA) or T-score. The second is the expected BMD for a

person of the patients same age and sex which is their age matched (AM) score or Z score. The two graphs are usually superimposed on a report printout so that both values can be visualized simultaneously, as shown in Figure 21. The patients BMD score can be compared in turn to each of these two reference scores. The difference between the patients score and the normal reference is expressed as a standard deviation (SD) above or below the average (NOF, 2000). In the report shown, which is for a spine scan, the patient was approximately 40 years old. Their BMD readings are shown for different groupings of the lumbar vertebrae. L2, L3 and L4 are shown and a combined figure of L2-L4 which has a BMD of 1.189 g/cm2 and this when matched to a YA is only -0.1 SDs below the average. The age matched score is -0.3 SD and can be seen in the adjacent column. The blue shaded area is comprised of all Z-score values i.e. values which are between +1 and -1 SD from the average for each age. Behind that, the bands ranging from dark green to red are referring to YA values or T-scores. Light green and the top half of yellow are SD's in the osteopaenic range. Dark green is normal. This procedure is exactly the same in principle for hip scans or forearm.



Region	BMD (g/cm²)	YA (T)	AM (Z)
L1-L2	1.067	-0.7	-0.9
L1-L3	1.124	-0.4	-0.6
L1-L4	1.133	-0.4	-0.6
L2-L3	1.209	0.1	-0.2
L2-L4	1.189	-0.1	-0.3
L3-L4	1.186	-0.1	-0.4

Figure 21 Example graph for a Spine BMD Measurement

The World Health Organization (WHO) definition of osteoporosis in Table 10 shows the WHO definitions of bone density categories (WHO, 1994). A physician receiving a report of a BMD scan would use these criteria to describe the patients condition. DXA is the method of choice for measuring bone density as recommended by the WHO.

BMD T-score of above -1	Normal at the measured site
BMD T-score -1 to -2.5	Moderate osteoporosis (Osteopaenia)
BMD T-score below -2.5	Osteoporotic
BMD T-score below -2.5 and one or more fragility fractures	Severe (established) osteoporosis

Table 10 WHO Criteria for Diagnosing BMD Results

4.9 Accuracy of Measurements

QUS accuracy was studied by Cheng *et al* (2002) who concluded that variation in bone size might affect the accuracy of measurements. QUS is used in this study as the first method of BMD measurement because it is simple, safe, inexpensive and portable. A benefit of ultrasound is that although the BMD results may not correlate highly with DXA results, it has been found to be able to predict fracture risk just as well as DXA (Bauer *et al*, 1997). The Sahara QUS machine used in this research was one of two QUS machines studied by Cheng's group. The machine has the disadvantage of having fixed transducer positions in relation to the foot plate which means that feet of different sizes would have measurements done at varying positions on their heel. This could lead to inter-individual variation and also intraindividual variation (if the foot size changed considerably in an individual through increased age or weight gain/loss). The study had only a very small number of participants, 12 males and 14 females. A comparison of the results from QUS to two DXA measurements was made, one of the region which was used by the fixed QUS transducer and the other of the optimal region as decided by the individual's foot length. Results showed that calcaneal length and soft tissue thickness had a substantial effect on BMD. However, the study could not use QUS to scan at the desired location and had to base assumptions on DXA results, which may not be representative. As long as the foot is of a minimum size, the area of measurement should not include any cortical bone and therefore will be comparable for each individual.

4.10 Choosing Who, and Which Anatomical Site, to Scan

Since BMD can be measured very simply and with minimal dose it may be considered

as a test to employ in a mass screening programme. However, to-date BMD has not been taken up as a screening test. A meta-analysis in Sweden (Marshall *et al*, 1996) summarized that since BMD cannot indicate who would fracture, only the risk for fracture, it was not worth recommending a screening programme. The analysis included more than 2,000 fractures and 11 study populations totaling around 90,000 people, all women. Further results from the study were that any site of the body had almost the same predictive ability of fracture risk for a decrease in bone density of 1 standard deviation below the mean which means that any anatomical site could be used. However, above that the measurements for the spine better predicted spine fractures and measurements at the hip better predicted hip fractures. Thus, in postmenopausal women the current guidelines are to scan both hip and spine in order to most accurately assess each sites independent risk of fracture.

In general, for diagnosis of low BMD, the total hip DXA reading is thought to be the most reliable, as advised by the International Osteoporosis Foundation Committee of Scientific Advisors (Kanis and Gluer, 2000). The total hip measurement will be the DXA result used for this study.

When considering who to screen for low BMD, normally attention would not be on young, healthy adults but directed at older people and particularly perimenopausal women. However, to help physicians think about who should be monitored with bone density testing, the Royal College of Physicians (2000) published a list of indications as can be seen in Table 11.

- Radiographic evidence of osteopenia and/or vertebral deformity.
- Previous fragility fracture.
- Prolonged corticosteroid therapy (prednisolone >7.5 mg daily for six months or more).
- Premature menopause (natural or surgical menopause before the age of 45 years).
- Prolonged secondary amenorrhoea (>1 year).
- Primary hypogonadism.
- Chronic disorders associated with osteoporosis.
- Maternal history of hip fracture.
- Low body mass index (<19 kg/m^2).

Table 11 Royal College of Physicians Indications for BMD Measurement

Most of the indicators for BMD measurement, as listed in Table 11, would not be expected to be present in the study participants, except for possibly amenorrhea of more than 1 year or low BMI (<20 kg/m^2), but will be questioned for on the lifestyle tool. Questions on the tool would also reveal a fragility fracture although again this is thought to be unlikely to have occurred to any participant.

4.11 Fracture Risk and Low BMD

Between 1997 and 2000, including follow-up, The National Osteoporosis Risk Assessment (NORA) study in America was used to discover unknown low BMD in postmenopausal women, risk factors and fracture incidence. Results published by Siris *et al* (2001) showed the data collected during the time frame mentioned. This very large study included 200,160 women from across 34 states. Four different technologies were used for BMD testing, heel SXA, forearm pDXA, phalanges pDXA and calcaneal QUS. Risk factors were assessed by questionnaire and included the following: age, racial/ethnic background, height, weight, age at menopause, post menopausal oestrogen use, maternal history of osteoporosis, personal and family history of fracture, cigarette smoking, exercise, use of calcium supplements, use of thyroid hormone, cortisone, or diuretic medication, and caffeine and alcohol consumption. A multivariate analysis was used to control for differences in technique and site of measurement because of the known discordance between them. Twelve months after enrolment in the study, each participant was sent a follow-up questionnaire asking about fracture incidence during the past year. For each category of BMD, normal, osteopaenia and osteoporosis, fracture rates were described. The important finding from this data was that, overall, having a diagnosis from BMD measurement of osteoporosis meant a 4 fold increase in rate of fracture than a normal BMD. Women with a diagnosis of osteopaenia were 1.8 times more likely to fracture than normal. Thus the link between BMD and fracture risk was strongly corroborated.

NORA in 2001 was the largest study conducted in the US on postmenopausal women and so it is very important to note that almost half the 200,160 participants who were not known to have osteoporosis did have low BMD. This result was consistent with the earlier reported finding of, and estimated prevalence of, 50-68% low hip BMD among women aged 50 or older in the Third National Health and Nutrition

Examination Survey (NHANES III) which included 3,175 women (Looker *et al*, 1998). Thus, the link between low BMD and fracture incidence is firmly established.

4.12 Magnetic Resonance Imaging

4.12.1 General

It has been commented on, earlier in this work, that BMD and bone mass do not describe the full picture of bone susceptibility to fracture. QUS for example, using some other method than bone mass, is able to detect fracture risk independently of BMD correlation (Bauer *et al*, 1997).

Very recently, many studies have targeted bone microarchitecture as the new direction in bone studies. It is hoped that a combination of BMD and microarchitectural description may be a more accurate way of determining fracture likelihood. The method of measurement in this case is either magnetic resonance imaging (MRI) or computed tomography (CT). Different techniques are being reported and some of these will be discussed here. It is intended that this project will employ one of the methods (MRI) to image some normal and some low bone density subjects identified in the research.

A group in Hong Kong described their work on 44 seventy year old women who they compared to 20 twenty eight year olds (Yeung, 2004). They examined the echo-planar diffusion of vertebral body marrow with quantitative MR diffusion imaging. They concluded that a decrease in diffusion values which indicated an accumulation of fatty bone marrow could be helpful in the study of osteoporosis.

Another way of making use of MRI to augment BMD measurements was devised by Arokoski *et al* (2002). They conceived a method of using MRI to convert the 2 dimensional measure of BMD to 3 dimensions using MRI. The hypothesis was based on the principle that not being able to correct for femoral neck size could lead to incorrect estimations of BMD. The study also assessed the feasibility of assessing bone mineral status with MR T_2* relaxation time, which is the decay constant for randomization of the in-phase dipoles (Curry, 1990, p453). Interestingly, the study was

conducted on men. Only 28 participants were included, who were healthy 47-64 year old males. The volume MRI measurement correlated with the estimated BMD volume however the MRI figure was 18% lower. T_2* relaxation time correlated negatively with BMD. The group concluded that allowing for bone geometry led to lower DXA values suggesting current methods may overestimate BMD. They also suggested that T_2* MRI approximates BMD measures.

In another relatively small group of female subjects, pre and post menopausal, lumbar spine MR perfusion was compared to BMD (Shih *et al*, 2004). 69 pre and post menopausal women were included with some of the post menopausal group receiving hormone replacement therapy. Using time-signal intensity curves from dynamic MR imaging, peak enhancement ratio was calculated to represent bone marrow perfusion. Marrow perfusion correlated well with BMD for all subjects ($n=69$, $r=0.63$, $P<0.001$). It was suggested from this data that there could be a vascular component to osteoporosis.

Perhaps the most exciting development regarding bone structure and MRI was the introduction of 3 dimensional imaging of the architecture of trabecular bone. As an example of this, the work by Gomberg *et al* (2000) describes an approach which characterizes quantitatively the microarchitecture as a network of rods and plates using digital topology. Boutry (2003), in France, relates the experience of using MR to look for differences in bone of men with and without osteoporosis. 50 men were studied, and apart from DXA BMD they had 10 consecutive sagittal 3D gradient echo MR sections of the calcaneus analysed with a rectangular region of interest obtaining 20 structural measurements. 13 out of the 20 parameters for MR showed significant differences between normal and osteoporotic men.

4.12.2 Magnetism and Radiofrequencies

MRI developed from nuclear magnetic resonance (NMR). In 1972, Lauterbur gave the name zeugmatography to the technique of joining a radiofrequency (RF) magnetic field with magnetic field gradients that created spatial information, producing the first NMR image. The name was, not surprisingly, subsequently changed to MRI.

MRI physics begins with the concept of the angular momentum of a nucleus, i.e. it's rotational motion in terms of direction and magnitude. In fact there are two types of rotational motion which are orbital and spinning. Nucleons are held to each other by a large nuclear force and both the protons and neutrons can be imagined to be orbiting around the centre of the nucleus. Nucleons of the same type pair with each other thus canceling out their spin angular momentum. But when there are uneven numbers of either neutrons or protons it results in nuclear spin. Nuclei with nuclear spin have a magnetic dipole moment (a measure of the strength or size of magnetism) and will align themselves along a magnetic field.

Several nuclei fit this criteria but the one which is currently of most importance to MRI is hydrogen with a nuclear spin value of 1. Whilst the nuclei try to align themselves to the external magnetic field they also precess at a certain unique frequency called the Larmor frequency. Two further important points are that the Larmor frequency depends on the magnetic field strength and that it is in the RF range of the electromagnetic spectrum. Note also the nuclei do not all spin in phase with each other.

Based upon the physical principles described above, MRI involves placing the patient in a uniform magnetic field with direction Z, then moving the phase and direction of the hydrogen nuclei (protons) with a second magnetic field and finally noting the signal received as the nuclei return to their original state. The second magnetic field is produced by a RF pulse from a transmitter, which can also be used to receive signal. When the RF energy is absorbed by the nuclei it is termed resonance.

In order to visualize an image inside the body, it is necessary to define voxels of information within a particular slice of anatomy. Gradient coils are added to the system, inside the bore of the main magnet, in order to achieve this, which have a varying magnetic field strength from low to high along the same Z axis as the main magnet but over a shorter length. Utilising the fact that a nuclei will only respond to an RF pulse if it is at the Larmor frequency of it's precession, and that the Larmor frequency depends on the field strength which varies across the gradient coil, then applying a particular RF will select a particular slice of the magnetic field. To allow each voxel in a slice to have a unique signal the phase and frequency of precession is changed through two further gradients in the Y and X directions (Curry, 1990).

A fuller explanation of MRI cannot be given space here but in summary, due to the difference in tissue response to RF pulses, anatomy is demonstrated in great detail.

4.12.3 MRI Principles of Operation

Control of the group of parameters which determine everything about the acquired MRI image is through choosing a pulse sequence which has characteristics suited to the nature of the image required. The technique of producing high resolution images which was to be piloted in this study was the one described by Boutry *et al* in an article in Radiology in 2003.

4.12.4 MRI Techniques

These sagittal images of a control (C) and an osteoporotic (OP) person show how high resolution MRI imaging can give a visual impression of bone loss (Boutry, 2003). The details of this scan acquisition method are described here as they were replicated for the scans done in Al Qassimi Hospital MRI department. White indicates bone and black indicates marrow on this image.

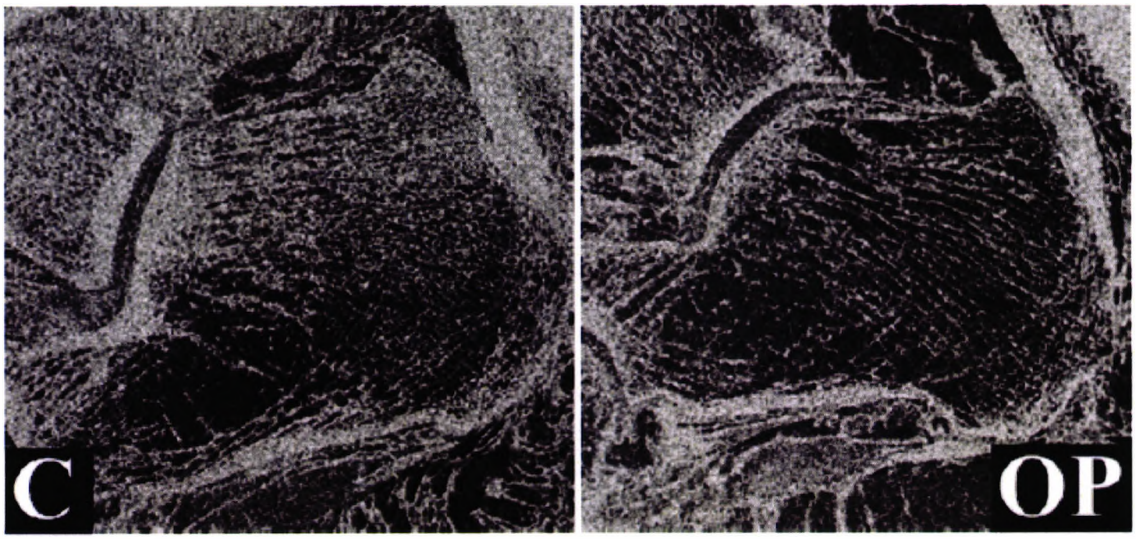


Figure 22 High Resolution MRI of Calcaneal Trabeculae

The scan was done with the person lying supine on the couch and entering the machine feet first. The Siemens small flexible coil was wrapped around the calcaneum with soft cotton padding placed inside for comfort. The coil was secured in place with velcro straps and foam pads were used either side of the foot to keep it vertical in the

correct position. A small pad was used under the knee to make the position more comfortable which helped the person to remain motionless for the duration of the scan time. Localizing images were taken coronally and sagitally to find the site of interest before the full acquisition was started.

The full study was a three dimensional (3D) set of images using a fast imaging with steady-state precession (FISP) gradient echo sequence. 3D imaging allows thinner slices to be taken because the slices are contiguous. The parameters selected were: a repetition time (TR) of 24, echo time (TE) of 12, flip angle 25 degrees, field of view (FOV) 100, repetitions 2, base resolution 512, phase resolution 439 (86%) and section thickness 0.7 mm. This resulted in a spatial resolution of 0.2 x 0.2 x 0.7 mm. The acquisition time was approximately 16 minutes and more than 50 slices were produced.

Structural Parameter	Parameter Type
Apparent bone volume/tissue volume	Histomorphometric
Apparent trabecular bone parameter	Histomorphometric
Apparent trabecular thickness	Histomorphometric
Apparent trabecular number	Histomorphometric
Apparent trabecular separation	Histomorphometric
Apparent trabecular partition	Connectivity
Apparent bone marrow partition	Connectivity
Trabecular bone pattern factor	Connectivity
Euler number	Connectivity
Star volume of marrow space	Connectivity

Table 12 Trabecular Parameters from MRI

The article described how many parameters could be measured from this technique once the image was binarised and transferred to a personal computer, see Table 12. An adapted software programme performed image texture analysis. Some of the parameters refer to the connectivity and some to the histomorphometric properties of the bone. Euler number relates to the property of the surface of a structure, highly connected trabecular networks have lower Euler numbers than poorly connected networks. Star volume is a method of drawing rays in all directions from a random point in the trabecular pattern until they connect with another trabecular strut. The shorter the lines are, the better connected the network.

This processing software is usually developed in-house by a group of expert physicists and was not available for this study, however piloting the scan technique allowed for feasibility to be assessed and the images to be stored for later analysis should the

software become available. The technique is extremely exciting in that it addresses both density and quality of bone.

4.12.5 Siemens Magnetom Symphony 1.5T MRI Scanner

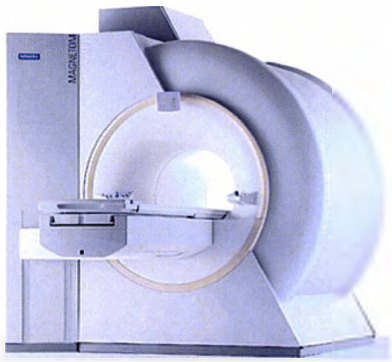


Figure 23 Siemens MRI Scanner

Tesla (T) is the standard international (SI) unit for magnetic field strength. MRI clinical machines vary from 0.5 to 3.0 Tesla. The Siemens Symphony is quite powerful at 1.5T. The highest strength allowed for clinical applications is 3.0T although research machines may be up to 7.0T. One T equals 10,000 gauss (G). The earth's magnetic field strength is 0.6 G and the general public is not usually allowed to be in any area of more than 5.0 G.

4.13 Safety Issues

4.13.1 DXA Radiation Safety

DXA uses radiation and therefore creates a safety issue. However, the exposure is very small, approximately 2.5 μSv for one anatomical site which is much less than that experienced on a transatlantic flight, approximately 60 μSv, and even less than the exposure from 1 day of normal background radiation which is approximately 7 μSv (Langton, 2000). The annual exposure from background radiation is 2,400 μSv at sea level. The radiation risk is considered to be negligible for this procedure.

4.13.2 Ultrasound Safety

Ultrasound is not an ionizing radiation and is deemed safe. The previously discussed contraindications should be the only consideration regarding safety.

4.13.3 MRI Safety

MRI, as yet, has not been found to have any adverse biological effects and so is safe to use however there are many safety considerations to take into account before embarking on a scan. All patients and personnel must be screened prior to entering an MRI suite. An MRI screening questionnaire must be completed because metal implants or devices cannot be allowed into the scanning room as they would be pulled towards the large magnet possibly harming those in their path. Small objects such as hair pins can reach speeds of up to 40 miles per hour when pulled into the magnetic field (Westbrook, 1980).

5. METHODOLOGY

5.1 Study Design

The design of this research study is a cross-sectional survey of university and college students. It is an analytical, observational study. The participants are volunteers, and represent the student population as a whole. The sample is stratified into sub-groups of university males, university females and college females.

The study will measure bone strength with one to three different techniques for each student. Correlation will be analyzed between the results of the measurement methods. Nine listed risk factors will be assessed and comparisons made between males and females for presence and severity of risk. Means of bone strength measurements for students with risk factors will be compared to those without, in order to define the impact of the risk on bone strength.

5.1.1 Target and Study Populations

A population is a complete set (a total of N subjects) of persons or objects that possess characteristics which are of interest to the researcher. This population can be divided into two groups. The first is called the target population and includes all people who meet the set of criteria of interest to the research (Pagano and Gauvreau, 2000). In this case it is young (18-25 year old) adults of Arab ethnicity.

Although the target population is initially university and college students, because further education in the UAE is so prevalent the sample could also be said to be from the target population of young adults in the UAE. All Nationals study for free up to university or college level in the public sector. Expatriates are well catered for in the private sector and although some institutions are expensive the fees for the University of Sharjah are heavily subsidized by H.H. Dr. Sheikh Sultan Al Qassimi, the Ruler of Sharjah. There are also many scholarships available from a variety of bodies, including the armed forces and government ministries. Education is a very high priority in the UAE.

More than 80 per cent of National students who graduated from secondary school in

1999 took up a place in higher education in September 1999. According to the National Admissions and Placement Office (NAPO), 90 per cent of female students and 73 per cent of their male counterparts commenced courses at either the federally funded Higher Colleges of Technology (HCT), established in 1987, Zayed University (ZU) for women, established in 1998, or the United Arab Emirates (UAE) University at Al Ain, established in 1977. In September, 2004, 13,560 National students applied to these three institutions. In the expatriate community there is also a high level of secondary education because families are generally financially secure. Expatriates are only in this country because one or both of their parents have a job and sponsorship. Very often this includes school fees as a company benefit. Lower income jobs do not permit the whole family to enter the country as residents.

The second type of population is called the study population (a total of *n* subjects). The rationale for using a study population is that it is not normally feasible to include all of the target population in the research project. This may be for several reasons, some of which are described in the following list:

1. there is a risk to the participants,
2. *N* may be very large,
3. the target population may not be accessible in its entirety,
4. the cost would be too high,
5. the study would take too long to perform.

In the case of this research project all of the above points are valid except number 3, and therefore a sample population is to be used.

5.1.2 Sampling Technique

There are two types of sampling method which can be used to select a study population or sample which are probability and non-probability (Nieswiadomy, 2002, p170). The first type, probability, is the best way of ensuring that the target population is accurately represented without bias.

Probability sampling can be subdivided into; 1/ simple random – each subject is chosen

randomly from the target group with an equal chance of any target member being chosen each time, 2/ systematic – subjects are selected on the basis of some regularly occurring characteristic, such as every third person on the complete list of target subjects or 3/ cluster – systematic or random samples are selected from clusters such as higher education institutes in the UAE.

Non-probability, the second type of sampling technique, is when the subjects are recruited for the study in a non-random manner. This method is more likely to show bias. Non-probability sampling can be subdivided into; 1/ convenience – also called accidental whereby readily available people are chosen, 2/ quota – the subjects are divided into sub-groups for each of which a required number of subjects is specified and 3/ purposive – judgmental because the researcher chooses subjects based on their belief as to the suitability of the subjects to be representative.

The sampling technique for this research is convenience, stratified to obtain a sample of males and females. Although a complete list of the target group, students at the university and college, could be obtained, it was felt that it would not be feasible to employ the random method of sampling. To perform random sampling, the selected participants have to be contacted and asked to be involved in the research. In this Muslim, conservative, community it is not always acceptable for students to be directly contacted for reasons of privacy and intrusion. Many students may only be approachable through their parents and those parents may not speak English. The current generation in the university at this point can be very different from their parent's generation. This country has been through rapid growth and change over the past few decades and parents may not be as open to new situations as their children, causing possibly a large amount of non-compliance. Allowing participants to volunteer was thought to be a better way to get the required numbers and more likely to succeed.

5.1.3 Bias

It is possible that the study population may not represent the target population, regardless of the method by which it was sampled. If the two populations differ in some important way the study population is biased. Bias is caused by the researcher and every effort will be made in this study design to avoid bias. Anticipated bias which

could have occurred is that only students who speak English volunteered, or only health science students. The method of convenience sampling in this case aimed to be as unbiased as possible through a poster and brochure advertising campaign which was seen by as many of the students as possible, and by allowing walk-in volunteers. The sample was audited to check for distribution of volunteers from all colleges. This at the same time confirmed non-English speakers were represented as some of the colleges operate in Arabic only.

At all times of data collection, an Arabic speaking assistant was present for Arabic/English translation between the researcher and the students, to help with questionnaire completion and to encourage participation which may have been hindered by the obviously Western appearance of the main researcher. It was correctly assumed by the students that the main researcher was not fluent in the Arabic language, however she was able to speak and understand limited Arabic and often explained points or translated English words into Arabic. Where it was deemed appropriate, images were used to supplement words, particularly for the questionnaire on food consumption. This was an improvement made after a pilot study showed difficulties in completing the calcium intake portion of the lifestyle questionnaire.

Although the literature was mostly in English, the students tend to share new information efficiently between themselves and, as it was expected, once informed by their peers of the project, speaking little English was not a barrier to their participation. Therefore, a representative sample of the target population was collected. To avoid only collecting health science students, the research posters and brochures where distributed to all colleges and the admissions and registration building (a central area for all students) two weeks before data collection was due to start. Students seem to have only a short-term interest and memory for upcoming events and it was thought that two weeks would allow enough time for word to get around about the study but not long enough that the notices would have been forgotten about before the due date. The initial advertisements were deemed successful as they provoked some students to call the researcher to ask for more information and permission to join the study in advance of the start date. The time frame for volunteers to be able to register (the data collection continued throughout a whole semester of 16 weeks) was long enough that all students had the opportunity to be involved.

5.1.4 Sample Size

As a generalization, the larger the sample, the more representative it is of the target population (Nieswiadomy, 1998, p181). However, it is also mentioned that sometimes only small sample studies are feasible but they are at least a start if the area being investigated is new territory and by replicating them the weight of evidence will build if several investigators produce the same result.

There were 403 students in the college of Health Sciences alone, one of 11 colleges at the University of Sharjah. The target population of female students at the UOS was (May 04) 2,777 undergraduates, the population of males was approximately equal giving a total student group of 5,935. DWC enrolment was approximately 2,000 female students divided amongst those in foundation, certificate and higher level diploma courses. Academic courses varied and included business, information technology, communication, education and health which broadly matched with courses at the UOS.

The study was implemented in phases. It was anticipated that not all participants would complete each stage and would drop out for various reasons, the main focus of data collection was to try to ensure a QUS study for all participants and then as many as possible would go on to have DXA at an offsite location but only a limited number to be offered MRI.

A sample size calculation to determine the number of participants required was performed based on a pilot study using the Sahara QUS machine and the result of estimated BMD. The number of students required to ensure that 95% of the samples mean bone strength measurements for estimated BMD lie within ±0.015 g/cm^2 of the population mean value is shown below (Daniel, 2000). The level of confidence is set at 95%, therefore z = 1.96 for a 2 tailed test. The population standard deviation is unknown and pilot data is used, σ = 0.07 for males and females. The width of the confidence interval needed (as defined by the researcher from literature) in each direction, d, is to be 0.015g/cm^2. The range of 0.03 g/cm^2 represents only 5% of the value for BMD of 0.56 g/cm^2 and is within the limit of 20% which would be acceptable. This indicates a required sample size of n = 84 for each group.

$$n = \frac{z^2 \sigma^2}{d^2}$$

$$n = \frac{1.96^2 \times 0.07^2}{0.015^2}$$

$$n = 84$$

Equation 1 Sample size

This number was used as a targeted minimum for the QUS part of the study but recruitment was open and the aim was to include as many as time and finances allow. The larger the sample size, the greater the power.

Differences of 9% in BMD between ethnicities, and 8% in BMD for exercise participation, have been shown in the literature (Mussolini, 2001, Mackelvie, 2001). If a 9% difference was expected, using the same formula, the sample size required would be only 30. This was the target number for the DXA studies as it is a more difficult study to do for a variety of reasons already discussed but including time constraints of taking the students off site on a minimum 3 hour round trip.

Taking a different approach, for this study to discover whether the mean bone strength of Arab females is different or the same as the European mean, a power calculation (Pagano, 2000, p246) is needed based on the expected size of the difference between the two means based again on pilot data. The calculation is shown below. The pilot study mean, x, is substituted for μ_1 population mean, α error is set at 5% and power at 80%. This is a two sided test although as the expected difference (based on previous studies) is that the Arabic bone strength will be lower than the European a one sided test could have been done. The results showed that 96 students would be required in the study population.

$$n = \left[\frac{(z_{\alpha/2} + z_{\beta})(\sigma)}{(-\mu_0)} \right]^2$$

$$n = \left[\frac{(1.96 + 0.84)(0.07)}{(0.56 - 0.58)} \right]^2$$

$$n = 96$$

Equation 2 Power calculation

Should time and finances allow this second target number for the QUS part of the study to be reached, the study would have 80% power to determine if Arabic bone strength is lower than European bone strength as determined by QUS. The sample sizes required therefore are shown in Table 13.

Sample	Min. no. *	Min. no. **	Min. no. ***
Females UOS	96	84	30
Males UOS	96	84	30
Females DWC	96	84	30

*based on 80% power calculation (Pagano)
**based on sample size calculation and 5% expected difference (Daniel)
***based on sample size calculation and 9% expected difference (Daniel)

Table 13 Sample Size Requirements

For any sample, 30 is always considered a minimum target number because it is the number of samples needed for the distribution of results to approximate a normal curve (Nieswiadomy, 1998, p257) and to allow Z-score to be used (a standard score which indicates the number of standard deviations from the mean a result lies).

5.1.5 Sampling Error

Two types of error can be made when conducting hypothesis testing. A rejection error, also known as α, or type I, error is made if the null hypothesis is rejected when in fact it should not have been rejected. The second type is an acceptance error, also known as β or type II error and is made if the null hypothesis is accepted when it should not have been. The first calculation in the section on sample size accounts for type I error. The probability of avoiding a type II error is called the power of a test or the likelihood that a particular test will discover a difference from the null hypothesis if there is one. The required power of a test should not be set at less than 80%. It is included in the second calculation.

5.1.6 Inclusion / Exclusion Criteria

Those included in the study were healthy young Arab people of age 18 to 25 who had provided written informed consent. Participants were asked questions regarding their general health as part of the tool used for diet, exercise and lifestyle. Any conditions or medications known to effect bone density exempted the candidate from the study. Pregnant females were exempt as were those unsure whether they could be pregnant or not. Recent gastrointestinal studies using contrast agent, nuclear medicine tests, extensive orthopaedic surgery and severe obesity were also exclusion criteria. DXA has a weight limit of 114kg. Severe obesity (BMI 35 +) was an exclusion criteria.

5.1.7 Ethics Approval

Ethics approval was sought and obtained from the University of Sharjah Research Board and also the Dubai Womens College research committee. The approval letters can be seen in the Appendices.

5.1.8 Informed Consent

Informed consent was required from all participants. The consent form (F2) which was used can be seen in the Appendices. The consent form was signed only after participants had read the information brochure (F1), or had it explained to them in Arabic or English, and can be found in the Appendices.

5.2 Data Collection

5.2.1 Pilot Study

On 6th and 7th of April 2002 a pilot study was carried out to investigate lifestyle and QUS results for UOS students. The data collection was done during World Health week, which had been previously advertised to students by poster, and was conducted with participation from each of the health science majors in the college of health sciences. Each major offered a free health check, Medical Diagnostic Imaging offered QUS estimated BMD testing along with requesting volunteers to participate in this research.

The study was a cross-sectional survey of UOS students. The sample was convenience, being volunteers from attendees at the UOS main administration building, M11. The UOS had 6 colleges at that time with around 300 students in each, approximately 1,800 students in total.

A stand was set up in the main university building offering bone density QUS scans to students. The stand was open from 9.0am until 3.0pm on two consecutive days, one day for females and one day for males. Permission for conducting the study was first obtained from the Dean's office of the College of Health Sciences. The group of participants was a convenience sample of volunteers from the whole of the university (6 colleges). Participants were given a written and verbal explanation of the study and then asked to sign a written consent form. Each participant filled out a questionnaire asking about their normal exercise and diet. Females were asked about menstruation and whether they cover (wear a robe, gloves, head and face cover for religious reasons) when outside. Questions were also asked regarding smoking and number of carbonated, caffeine containing and milk drinks per week. Exercise was recorded as the number of days each week that exercise was done. The estimated BMD was obtained from scanning the non-dominant heel; this being the opposite side to that of the hand used for writing. The equipment was checked before and after scanning using the manufacturer's phantom. The heel scan was done following the instruction manual regarding skin preparation and foot alignment. The equipment was a Sahara (Hologic,

Waltham, MA, USA) machine. Height and weight were recorded for all participants on the day of the study. These measurements were available to students at the same site as part of the open day, from the nursing department.

Volunteers were provided with information in the form of text and images, detailing the requirements of the study, ensuring confidentiality, explaining the nature of the equipment and the time required. Informed consent was then obtained. The researcher was present throughout and able to help with any difficulties in filling in the form. see appendices.

A second pilot study was undertaken in February 2005, on the first 5 volunteers, to test the revised data collection tools and the replacement ultrasonometer. Following this a sheet of food pictures was added to the documents in order that volunteers could visually identify foods for the calcium intake portion of the lifestyle tool. No other changes were made and the second pilot results were added to the full study results. A clear indication of the time for completion of QUS and lifestyle of 20 minutes was arrived at as an average of the time taken for the pilot candidates.

5.2.2 Full Study

The new Achilles QUS equipment was delivered to the researcher on 13th February 2005. The DBM Sonic was delivered the same week. The full study data collection started on 21st February and completed on 9th April 2005. There was a slight overlap with DXA scanning which started on 28th March and completed on 15th May. A total of 11 MRI calcaneal scans were done; 4 on 26th May, 2 on 1st June and 5 on 9th June. The total time of data collection was 15 weeks which was the majority of the university and college Spring semester that ended on 18th May. The individual study components are described separately in the following sections.

5.2.3 Stage 1 – Advertising

A simple, colourful, poster was developed for advertising the study (appendix J). The Dean of the College of Health Sciences signed a letter drafted by the researcher which introduced and explained the research project to the rest of the UOS through college Deans. It also requested permission for the researcher to visit all other university

colleges, as per an attached schedule, and compliance with the researcher in facilitating data collection (appendix B). Along with this letter, a poster, the data collection schedule and some F1 information brochures were sent to all college Deans. All responses were favourable; no colleges refused permission to attend.

Participants were informed of the research project first by this poster being displayed on their own college notice board and then by brochure, detailing all aspects of the study and asking volunteers to register. All advertising and information literature was provided in English language. Periods of time were timetabled and notified for commencement of the study and walk-in registration. These data collection sessions took place in a variety of locations; the writer's office, the main registration buildings (male and female), the main foyers of each university college and the cafeterias. As the QUS machines were portable they were transported by the researcher to each site daily. Stage 1, QUS scanning, continued throughout the semester. The other areas selected for data collection were places with busy throughput of students to and from classes, and afforded maximum visibility.

In the case of the DWC, F1 brochures and data collection forms were sent in advance to a colleague in the medical imaging program. The imaging students were asked to help by passing word around the campus about the study. The day of the visit by the researcher for data collection there were notices displayed on electronic notice boards around the campus with full details about the study. Further to that, the day commenced with the researcher addressing faculty and students with a 40 minute presentation on the research project in a large auditorium. Data collection commenced immediately afterwards in a designated classroom and then was continued in a busy corridor of the campus on another day, one month later. On each of the campuses it was found, from questioning the volunteers, that the most powerful form of advertising had been word of mouth from one student to another.

In all the documentation each participant was assigned a research number, maintaining confidentiality. Contact information was required from volunteers. Contact information of the research organiser was provided to the volunteers.

5.2.4 Stage 2 – Consent and Personal Information

Once the researcher was in position, either students walked up to gain information about the study or the research assistant, or main researcher, approached them in order to explain the research project and invite participation after introducing themselves. If the student was happy to proceed with the research project, after being informed that the whole process may take 20 minutes depending on the queue, informed consent was taken. The consent form was part of the information literature given to participants initially along with a personal information form. The participant was then seated comfortably in a chair and the lifestyle instrument was completed. At all times both the researcher and the research assistant aimed to maintain a calm, friendly and approachable manner vital to the successful recruitment and retention of volunteers. In particular, sensitive female questions were addressed in a quiet and personal tone in order to not cause embarrassment in front of peers thus also trying to ensure honest answers. That there were always more volunteers than could be accommodated testifies to their success. In some cases the students opted to return later after a class or on another day.

The researcher had been a faculty member at the university for 6 years at the time of data collection and may have been familiar to some of the students. The backup of an Arabic research assistant, however, undoubtedly helped to make the respondants feel even more comfortable as the assistant's manner of dress, including head cover, was consistent with the students own culture.

At first point of contact, only the QUS measurements could be performed therefore it was necessary to obtain contact information in order to later request the students to attend for DXA or MRI. Students were asked for permission to be re-contacted and if the answer was negative it would have been recorded on the information sheet. No students refused this permission to be recontacted.

5.2.5 Stage 3 – Lifestyle Profile and QUS

Each participant filled in a questionnaire regarding diet, exercise and lifestyle. Data collected was both qualitative and quantitative. The lifestyle instrument consisted of two documents, one developed by the researcher but following the general principle of

many previous studies including a calcium calculation based on the questionnaire by the National Academy of Science (1997) and the other, the International Physical Activity Questionnaire (IPAQ) which is an internationally used and validated tool. It categorizes activity into vigorous, moderate and walking, and measures how much time was spent in each area and then gives a number for the amount of activity done. IPAQ began in 1996 when Dr. Michael Booth of Sydney, Australia, decided that he would form a group to develop a questionnaire for health related physical activity. An international team was appointed and met a year later at a World Health Organisation (WHO) meeting. The eventual result was the IPAQ; an instrument recommended as a viable method of monitoring population levels of physical activity globally for populations 18-69 years of age and available free from the internet.

Part of the questionnaire was a food frequency tool for establishing calcium intake. The Ministry of Health was approached in order to find out if there was any data on the normal Arab diet or studies of calcium intake in particular as background information but there was not, however the Ministry offered the contact details of a well known dietician to speak to for advice. After discussion the dietician suggested that the calcium tool was appropriate in her opinion and that there was only one relevant calcium containing food which was not present and should be added called laban. She suggested that it contained the same amount of calcium as an equivalent portion of cottage cheese and so it was added to that section of the questionnaire. The dietician had been working in this country for many years, was Lebanese, and had many Arab clients of all nationalities. She said that the Arab diet is not high in dairy products in her experience.

During initial piloting of this tool it quickly became clear that some of the food names were unfamiliar and varied by nationality. The remedy for this was for the foods to be displayed on an accompanying sheet of colour images (appendix Q) of each food and then the student could see the named foods in order to decide if they had consumed them or not. This method proved very successful.

Since some of the participants in the study were limited in their English language ability, all documentation relating to volunteers was explained in both Arabic and English. There was an Arabic speaking assisstant present at all points of data

collection. Assistance was given whilst completing the questionnaire if required, in order to reduce loss of data through unanswered questions. The information collected on this profile included height and weight, which was measured by the researcher at the same time. Height was recorded standing with a metal tape and flat object to read off the measure level with the top of the head. Weight was recorded from a commercially available set of bathroom weighing scales which were taken along to each collection day. Records were kept on file in English only. Pre-completed questionnaires (either done by the volunteer alone or with the research assistants help) were checked during the interview conducted by the main researcher at the time of QUS.

Heel or phalanges, or both, quantitative ultrasound (QUS) techniques were performed. Peripheral, calcaneal, QUS was done in the full study using the Achilles Express (Lunar, GE, Madison, WI, USA) machine. Both heels were measured. Dominance was considered to be right sided if the participant writes with the right hand and vice versa and recorded in the file. As phalangeal scanning took longer, only the non-dominant hand was scanned. Students were seated upright in a firm chair without wheels for all scanning procedures. All bone measurements were performed by the main researcher.

Hygiene was important and so a supply of wet-wipe towels was available for cleaning the researcher's hands, and the machine parts, between measurements. Foot preparation consists of cleaning the area to be scanned with an alcohol swab and then drying with a lint free cloth before applying coupling gel. For cleaning the larger parts of the equipment an alcohol spray, as dictated by the operating instructions, was used.

The results of the QUS measurement were given immediately to the students. As per the reference range on the Achilles, students were told their readings were within the normal range if they were not more than 1 SD below the mean of the reference range on the machine. They were also advised that this reference range came from Caucasian females and that this research was trying to find out if those results were the same as for Arabs.

For the females whose readings were in the osteopaenic range the advice was to consider going to their own doctor to tell them about this test and ask if they needed any further monitoring. It was explained to them that this did not necessarily mean their

bones were at risk of fracturing because there are many other factors involved in fracture and that it was not as likely to happen in young healthy people as it is to elderly and frail people but they were also told that it has been found in some Arab countries that some people are low in vitamin D through lack of sun exposure and that this was something their doctor could advise them further about. All students were told that they would be invited to have DXA and would be called at a later date. At the end of the process, the contact details of the researcher were stressed to the students and they were asked if they had any further questions.

5.2.6 Stage 4 – DXA

Although QUS was available permanently in the researchers office, it was not until after the scheduled scanning carried out around the campus had almost concluded that the timetable for DXA was started. A new schedule was created (Table 14) to allow an equal chance for males and females to be taken separately to Dubai for their scans. Participants were contacted to arrange a date for DXA scanning.

Date (2005)	M / F	No. of students booked	No. of students attended
28 March	F	10	7
30 March	F	10	10
4 April	M	10	7
10 April	F	12	7
11 April	F	7	5
13 April	F	10	6
17 April	M	9	5
18 April	M	5	3
20 April	M	6	0*
24 April	M	11	2
25 April	M	7	2
27 April	M	14	5
1 May	M	6	3
2 May	M	6	2
4 May	M	11	4
11 May	F	3	2

* Public Holiday announced
Total M = 33, Total F = 37

Table 14 DXA Schedule

A total of 70 DXA hip scans were performed during 16 visits to Al Baraha Hospital. As can be seen from the schedule in Table 14, there were more days allocated to males than females. The reason for this was that the researcher set a target minimum of 30

scans for each group and the female target was reached fairly quickly as 71% of those who made a booking did attend. The males were much more unreliable and only 39% of those booked actually attended. Part of the reason was that as the semester progressed there were more demands on the students time such as exams and assignments. The overall response was good in that students were not frightened off by DXA as an X-ray test. A total of 85 males made a booking which is 76% of the males in the study, not all of whom had been reachable by telephone.

All students were later given a copy of their results and the same explanation as for QUS. If they showed osteopaenia they were recommended to visit their own doctor with the result in order to be further checked for any underlying cause such as vitamin D deficiency.

5.2.7 Stage 5 – Data Entry and Cleaning

Each volunteer's record was separated by a coloured plastic divider with the research number written on the tab. There were a total of 6 files for UOS males, 6 for UOS females and 2 for DWC females. Each case was checked to identify any queries or unanswered questions. If any point needed further clarification or a question had been left unanswered then this page was marked by a coloured post-it paper. The research assistant was then able to go to each place in the files and contact the students for the answers needed. This was done either by telephone, text message or email. Students were unfailingly courteous and generous in giving their time to responding. Because of this there was almost no missing data.

The Achilles QUS results were initially printed on thermal paper, which does eventually fade, and therefore they were copied onto the questionnaire. Data entry to the SPSS package started in the middle of March. The main researcher entered all computer data personally, the research assistant then went through all paper files to correlate with the entered data and look for mistakes. After corrections the process finished on 15th June.

5.2.8 Safety

DXA uses radiation and therefore creates a safety issue. However, the effective dose is very small at 2.5 μSv per exam compared to natural background radiation which is 7 μSv per day and 2,400 μSv per year. DXA is able to measure the sites considered at most risk from osteoporotic fractures, the spine and hip. It can also be used for many other peripheral sites (Langton, 2000). This study minimized radiation dose by only scanning the hip, giving a total dose of only 2.5 μSv per student. This dose would be increased should the scan need to be repeated however the scanning was only performed by the researcher, a trained and certified bone density operator, to reduce error and improve precision. No repeat scans were done.

5.2.9 Quality Assurance

DXA scans and QUS results must be supported by quality control systems. Three factors are involved in the quality of scanning: 1/ equipment, 2/ patient and 3/ technologist. Proper procedures and protocols for scanning and trained operators help to ensure quality scans. The equipment manual was available and consulted prior to any scanning for all techniques.

All equipment was calibrated and checked with a phantom. Power supply and room temperature can affect calibration and this was taken into consideration. Patient cooperation is also essential for good quality scans. Artefacts and deformities must be determined. Operators must be consistent in preparation, positioning and analysis. To ensure consistency a spine phantom was imaged on each day of DXA scanning and the QUS phantom was scanned each day of use also. The following points were checked for completed DXA hip scans:

- Femoral shaft was straight
- Leg rotation was correct, lesser trochanter not, or minimally, visible
- No movement unsharpness or artefacts were present

QUS also requires care in quality control measures and an ultrasound phantom was scanned at the start of each session of QUS for both the Achilles and the DBM Sonic.

All scans for QUS were carried out in the same room once the QC procedure had been completed. The room temperature was kept constant continually by the air conditioning units which are normal for all buildings in this climate. QUS equipment and the phantoms are sensitive to temperature and therefore the equipment and phantoms must be left in the scanning room for a minimum of 1 hour in order to stabilize, prior to use or until the QC procedure had passed.

5.2.10 Reliability and Validity

All scanning was performed by the main researcher, who had been involved in bone strength measurement for over ten years and was both experienced and qualified in bone density. Using only one technologist can greatly improve the precision of measurements.

The lifestyle instrument, apart from the demographics and some health questions, came from well used and validated sources. The exercise portion was the International Physical Activity Questionnaire which came from the IPAQ Committee and the calcium intake portion was slightly adapted (one food type added) from the National Academy of Sciences. QUS and DXA are well used and accepted methods of measuring bone parameters. MRI for bone analysis in this context is still at the research stage.

The components of the questionnaire devised by the researcher closely followed similar studies which have been performed in the past (Saadi, 2003). In order to check for reliability questions were addressed in more than one way and correlations produced between them, the correlations can be seen in the results section.

Content	Question Variations and Overlap				Checks for validity
Age	Age?	Date of birth? (DOB)			Age & DOB must match
Ethnicity	Ethnic group?	Country of birth?	Country lived in longest?	Nationality?	Nationality & country of birth usually match,
Marital status	Are you married?	How many children do you have?			To have children must be or have been married
Menstrual regularity	How regular are your menstrual periods?	Date of last menstrual period (LMP)?			If periods regular, LMP should not be more than 4/5 weeks previous
Medical condition	List any medical condition you have	Are you taking any medication?	Have you ever had an operation?		If taking medication or had an operation, for what medical condition?
Sun	How much time do you spend in the sun?	Units sport per week?	Time spent exercising/ walking? (IPAQ)		Sitting in the sun is extremely rare therefore time in the sun should correlate to either walking or outside sports activities
Caffeine	How many caffeine containing drinks per week?	How many carbonated drinks per week?			Source of caffeine is often carbonated beverages therefore check for correlation between questions
Milk	How many drinks milk per week?	Cups milk? (calcium intake section)			If milk drinks per week is zero cannot be any cups of milk specified on calcium intake section, check
Sport type	List any sports you do	Vigorous/moderate exercise? (IPAQ)			These two questions should match
Sport frequency	Units sport per week?	Time spent doing vigorous/moderate exercise? (IPAQ)			These two questions should match

Table 15 Questionnaire Content Validity

Table 15 describes the areas where specific content was gained and then further questions were asked on the same topic for validation. The last column explains the method of checking whether answers conferred with each other. This method was used for all volunteers during the interview prior to QUS. The system of information gathering was either a direct interview (the researcher filled in the answers), or the participant filled the answers and the researcher checked them. A second check of the questionnaires was done at the main office, during data cleaning. If any points were found to need clarification, or did not match with another similar question, the volunteer was contacted either by phone, text message or email for further information.

If a confusing answer could not be verified the result was excluded.

Due to insufficient time and lack of resources it was not possible to perform reliability checks in the form of test-retest of the lifestyle tool. A decision was made, concerning the research design, that the tools used were well validated through previous research use and that the benefit of increasing the power of the results through achieving high target numbers of volunteers would outweigh the benefit of retesting, which would be difficult, time consuming and possibly unreliable. It was also felt that these individuals (young students), with great pressure on their time, would not be amenable to retest procedures however it is accepted that this is a flaw in the research process and that should this type of study be repeated, reliability checks should be performed in order to have more confidence in the lifestyle test tool.

The calcium content of the diet was measured with a section of the lifestyle questionnaire called "calcium intake". This was taken from a calcium calculator available on the Internet from Teach Nutrition which is an organization for teachers in Ontario, Canada. The calculator was originally devised by the National Academy of Sciences in 1997.

There has been much support for one day dietary recall which is relatively quick and simple to complete rather than a food diary which takes several days. For students it was thought that the fastest, simplest method would be most successful. Studies such as the one in Sapporo, Japan by Sato *et al*, show that one day recall is a valid method. They compared a food frequency questionnaire with a weighted food record, both filled in one day but on different occasions, and found that they were not significantly different in their results with a correlation coefficient of 0.512 ($p<0.001$).

The aim of this research was not to accurately discover the calcium intake of the students but to categorize bone density according to relative calcium intakes – from the highest to lowest, which this questionnaire did manage to achieve using the calcium intake tool.

The IPAQ is a pre-validated tool. In 1998-99, eight versions of the IPAQ were subjected to a validity and reliability evaluation on approximately 2,550 people.

Studies were conducted in 14 research centers in 12 countries on 6 continents using standardized methods and protocols. The purpose of these studies was to investigate the short-term, test-retest reliability. Subjects repeated the IPAQ over a 3 to 7 day period to check the test-retest reliability. Criterion validity was determined by asking the subjects to wear a Computer Science Applications accelerometer for 7 consecutive days. Moderate intensity activity was when the CSA counts were > 1952 and < 5724 counts per minute, vigorous intensity activity was when the counts were >5725 counts per minute. The correlation coefficient for retest was very high at 0.8. The criterion validity was 0.3 for the IPAQ compared to the accelerometer and was found to be acceptable. In 2005 the conclusion was due of a study assessing the use of IPAQ in 19 countries as part of the International Physical Activity Prevalence Study (IPS).

5.2.11 Precision

Precision is the ability to give the same measurement each time the measurement is taken and depends on the equipment and user. The precision error for the Sahara is reported by the manufacturer to be 2.3% and for the Achilles 2% but literature states that it is difficult to assess and controversy exists over how to express it (Gluer, 1997). A study of QUS in men (Adler, 2001) calculated a 2% coefficient of variation for the Sahara by measuring 1 man 31 times with repositioning each time.

Precision error for DXA is better than QUS, and is quoted as being 1.5% for the femur (Genant *et al*, 1996). Precision is not just dependent on the equipment, but also on the operator/s. If an inexperienced person performs the scans they may do them differently each time, as can also be the case if more than one operator performs scans on subjects in the study. Precision for this study was controlled by having the same person, the researcher, performing all scans. Precision for the operator can be calculated and requires 30 people to be scanned twice. QUS precision was 3% using the formula of root mean squared of the standard deviation of the 30 pairs of scans. For DXA repeat scanning would have to be approved by the ethics committee and the individuals involved. This permission was not sought. However, precision is improved by using trained, experienced operators and the researcher is dual qualified in both the ISCD Physician Bone Densitometry Certificate and the ISCD Technologist Bone Densitometry Certificate and has been performing bone densitometry since 1993.

5.2.12 Principal Researcher/ Assistants

The principal researcher was present for all data collection. Two research assistants helped with the project, both graduates of the University of Sharjah. They were native Arabic speakers. An Arabic speaker was present through all data collection for translation when questions were raised. Extra helpers were found on the data collection days from students who had free time, they gave initial explanations to other students whilst they waited to be seen by the main researcher.

Pilot studies are required in order to test data collection instruments. Any necessary alterations can then be made prior to full data collection. Pilot studies also provide information about the study population which can be used when calculating sample size. A pilot study was carried out for this research in 2002. When the full study started in 2005 the first few students served as a second minor pilot to check the new equipment and previous modifications from 2002. One adjustment from this second pilot was the addition of a pictorial representation of the foods on the calcium intake in the lifestyle tool. It also provided an accurate idea of the time taken to process one volunteer which was helpful for information purposes.

5.3 Statistical Analysis

5.3.1 Descriptive Statistics

Data collected in this study was both categorical (nominal or ordinal) and scale (continuous or discrete). The dependent variable being measured was BMD which in studies has been shown to be normally distributed in populations. The independent variables are a mixture of ordinal and scale data. Statistical analysis of the results was performed using the computer programme Statistical Package for Social Sciences (SPSS), version 13.0 and the appropriate statistical tests for the type of data. A p value of < 0.05 was counted as significant at 2 sides and < 0.1 at 1 side. Scale data was described by its mean for location and standard deviation for spread of data. Ordinal data was described by the median and the range.

5.3.2 Measures of Distribution

Data can be distributed in four different shapes; left skewed (most of the values in the top half of the range), right skewed (most of the values in the bottom half of the range), uniform (values spread approximately evenly across the range) or mound-shaped (values clustered around the middle and tailing off towards each end) including the Normal distribution (Bowers *et al*, 2001, p59).

If an expected Normal distribution is skewed it may be due to outliers. Sometimes, some values are a considerable distance from the majority and these are called outliers. In order to identify outliers in a normal distribution, the inter-quartile range was calculated. From these values, the upper limit was discovered and values above that figure considered outliers.

The analytical tests which can be used are different for different distribution types. Parametric tests were used for analyzing Normal data and non-parametric tests for other data. In order to determine whether data was normally distributed, data was examined to discover whether the mean and median were the same, tests of kurtosis (peak) and skewness were also performed. If skewness divided by the standard error of skewness is >1.96 or <-1.96 the curve is skewed. The same is true for kurtosis divided by the standard error of kurtosis. Normality was checked by observation of the graphic representation of the data and by using the one sample Kolmogorov-Smirnov test.

5.3.3 Comparison of Means

Bivariate analysis using the t-test was done to look for differences in the mean BMD between sub-groups. Levene's test for equality of variance was used prior to the t-test.

5.3.4 Correlations

Pearson's correlation r was performed for metric data. Spearman's correlation r_s was used for categorical data.

5.3.5 Regression

Where more than one risk factor was seen to correlate with BMD, a multiple regression model was constructed to account for confounding effects and to discover which risk factors independently predicted bone strength. However, if an independent variable correlated strongly with another independent variable, collinearity exists and only the strongest of these variables can be used in the model.

6. RESULTS

6.1 Introduction

This chapter will present the results of both the pilot study which was undertaken in 2002 and the full study which was performed in 2005, in that order. Both studies aimed to describe bone strength and lifestyle risk factors for osteoporosis, and any relationship between them, in UAE students. The full study used three bone measurement techniques and the pilot study one.

The groups were analysed for a variety of characteristics before the study objectives were assessed. Several checks were made to ensure the suitability of the sample as representative of the target population.

First the distribution of students across colleges was determined. Second the issue of age was considered because the available Caucasian references for the equipment used are for the age of 20 years and upwards. Reference ranges for this Arab population have not yet been compiled therefore information about the shape of the bone growth curve was not known. In the lack of any published data regarding the growth curve for this population it was assumed to be similar to Caucasian. Caucasian graphs show that there is constant bone strength between the age of 20 and 25. However, 18 and 19 year old results are not given. The sample ages of Arabs in this study were from 18 years upwards. In order to determine if there was any difference between 18 and 19 year old students and the rest, tests were carried out on the results for these age groups to see if they were statistically different from the other age group results. They could have been expected to have lower readings if PBM had not yet been reached for the anatomical area under consideration. The 18 and 19 year old results were not statistically different from the other age groups and they were all considered as one sample in further analysis. PBM is reached later in the phalanges in Caucasians and so this was assumed to be the case for Arabs also and therefore the actual measurements of BUA and Ad-SOS of the fingers could not be used, instead the Z-score (age matched) was used for analysis against risk factors. The answers are shown in a further section.

Third, to justify having one group of Arabs, nationality was explored to look for differences between nationals and non-nationals. Finally, academic institution of the females was examined. In the pilot study there were two groups; UOS females and UOS males. Three

groups of volunteers were in the full study as a group of DWC females was added. The original intention of the researcher was to add these two female groups together in order to increase the sample size for females however before this was possible it was necessary to check if all characteristics of each female group were the same; they were not. One of the following sections is devoted to the results of this analysis. Some differences were seen between the UOS and DWC females therefore the two groups were analysed both separately and then together as a group called all females.

Following on from the examination of the sample, the results of the full study are presented according to the thesis objectives. The distributions and descriptive data for each of the variables are presented for each of the sample groups.

Bone strength data is displayed, in the case of the full study, as results for all three measurement methods including how well they correlate with each other. A comparison of these Arab bone strength results with the Caucasian reference data is made.

The analyses of the effects of lifestyle upon bone strength, for each of the risk factors measured, are presented in the same order as the aims and objectives of the research project.

6.2 Pilot Study

The study included 65 students, 35 females and 30 males. Since QUS is harmless, no one was excluded. Lifestyle information and QUS results were obtained for all participants. In most analyses of results the students were divided into two sub-sets based on gender as reference values for BMD are different for males versus females.

6.2.1 Sample

6.2.1.1 Exclusions

The plan for this pilot study had just specified students as the target population and no preparation had been made to only include Arabs. On the day of data collection a small number of African students presented themselves as volunteers and were accepted. In relation to BMD, Africans are known to have a higher bone density so a t-test was done between Africans and Arabs BMD results in order to detect a difference in mean BMD, for the male group, as confirmation. The test did show a significant difference as expected, $p = 0.003$. The 4 African subjects were removed, leaving a group of Arabs for subsequent analysis. There were also 4 females of African ethnicity who were removed from the female group. The pilot study then comprised 26 males and 31 females.

6.2.1.2 Sample Size

The sample size was adequate for a pilot study. The number of females was more than 30 which indicates that, following the central limit theorem, the distribution should be normal as it is in the general population for BMD. The number of males was slightly less than females.

6.2.2 Distribution of Data

6.2.2.1 Variables

All variables from the data collection were entered into SPSS 11.0 for processing. Some new variables were created from existing data, for example BMI.

6.2.2.2 Test of Normality

Height, weight, BMI and estimated BMD were all found to be normally distributed according to the Kolmogorov-Smirnov test. This test compares the observed distribution to a theoretical distribution. Parameters of the theoretical distribution are estimated from the observed data. Absolute figures indicate the largest absolute difference between the theoretical distribution and the observed distribution. Large significance values ($p > 0.05$) indicate that the observed distribution corresponds to the theoretical distribution i.e. it is normal. Many of the risk factors were not normally distributed and have been treated accordingly in the analysis.

6.2.3 Representativeness of Sample

It was stated in the introduction that all Arabs would be considered together because although their origins may have been from across the Arab world they have mostly lived in the same environment together and thus been exposed to the same cultural, physical and nutritional background. Their situation is further explained in the following three sets of pie charts.

6.2.3.1 Country of Birth

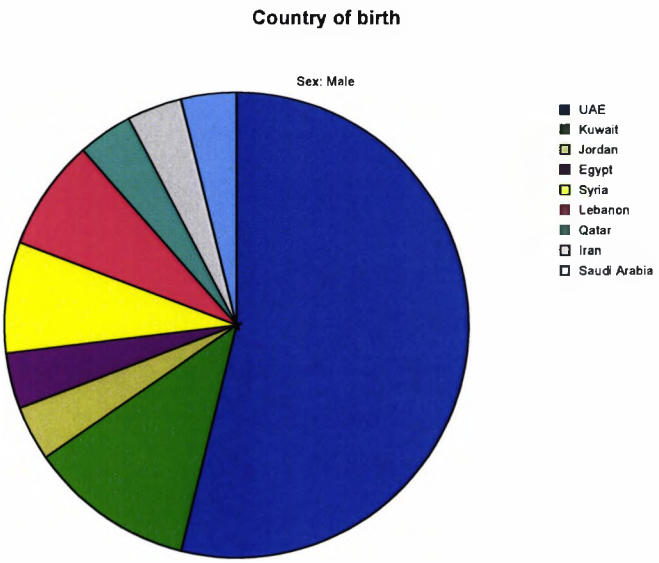


Figure 24 Country of birth, males

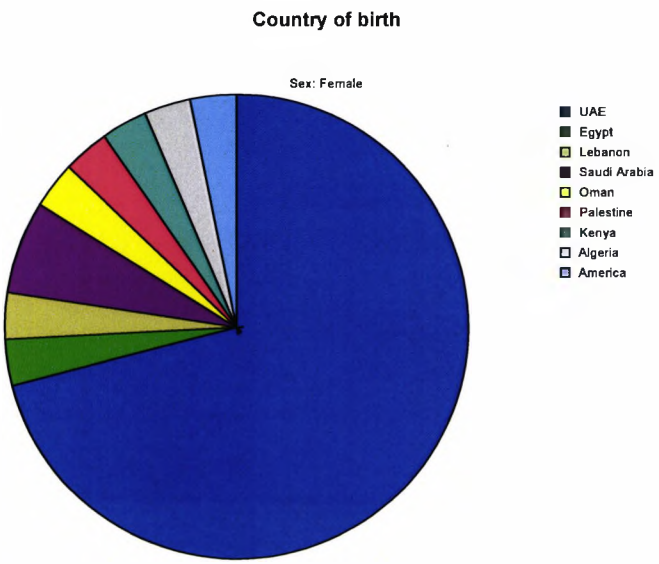


Figure 25 Country of birth, females

A large majority of the students were born in the UAE.

6.2.3.2 Domicile

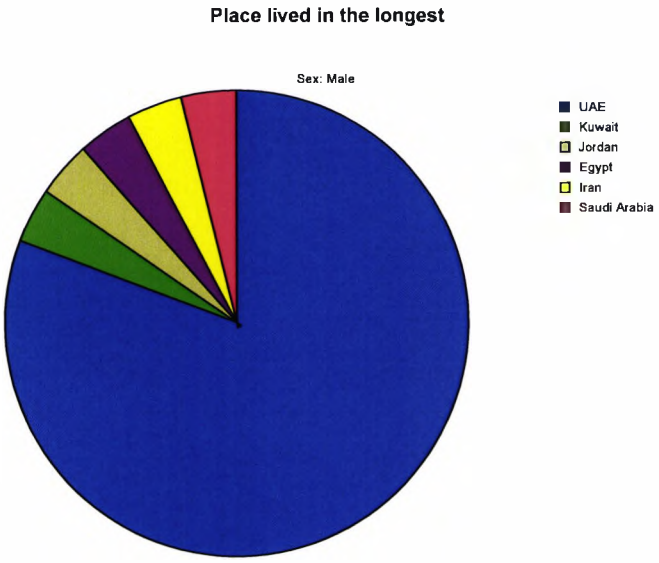


Figure 26 Domicile, males

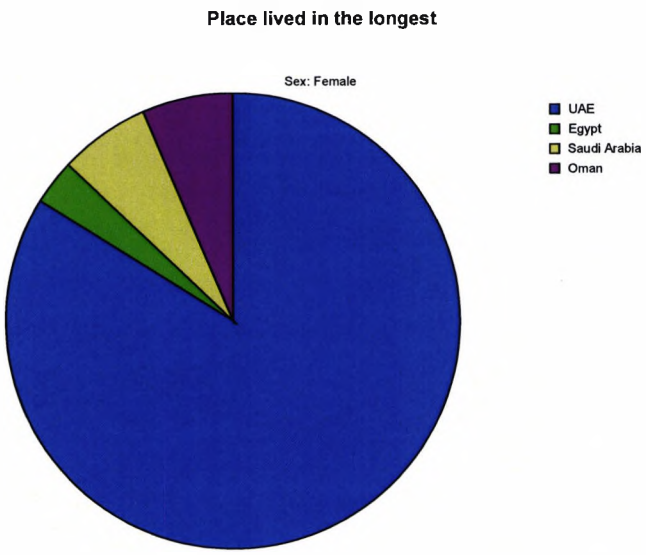


Figure 27 Domicile, females

Approximately 80% of all students had lived most of their life in the UAE.

6.2.3.3 Nationality

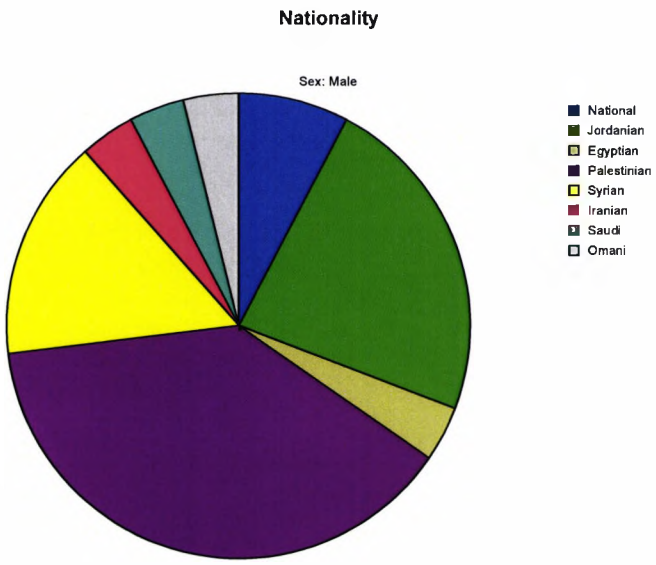


Figure 28 Nationality, males

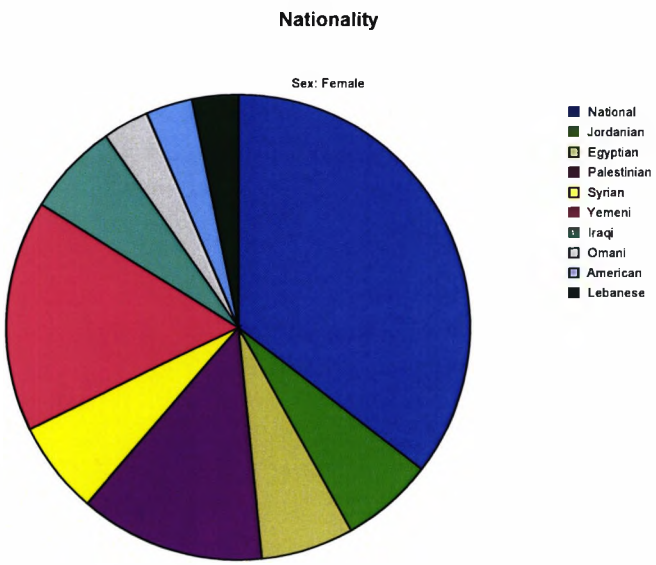


Figure 29 Nationality, females

It can be seen from these pie charts that the nationalities were very varied. However the domicile and place of birth are predominantly the UAE confirming that this is a group of Arabs who have all been brought up in the same place.

6.2.4 Subject Characteristics

6.2.4.1 Descriptives

The following table shows the descriptive statistics for the pilot data which is Gaussian, males and females. All QUS parameters are shown but bone strength analysis has only been done using estimated BMD, as it represents a combination of the other parameters.

Variables	*Males (n=26).*	*Females (n=31)*
Age (years)	20 (18-22)	19 (18-23)
Height (cm)	175.5 ± 6.3	159.5 ± 6.6
Weight (kg)	80.6 ± 17.8	57.5 ± 8..4
BMI (kg/m^2)	26.1 ± 5.4	22.6 ± 3.1
BUA (dB/MHz)	99.4 ± 13.7	77.8 ± 12.4
SOS (m/sec)	1,520.5 ± 19.5	1,560.7 ± 16.7
QUI	119.0 ± 19.6	100.6 ± 10.7
est. BMD (g/cm^2)	0.574 ± 0.071	0.560 ± 0.067

Table 16 Pilot Data Baseline Characteristics

6.2.5 Bone Strength Results

Bone strength was measured using calcaneal QUS. This machine gave an estimated BMD result based on the stiffness value. The histograms for these results are shown below.

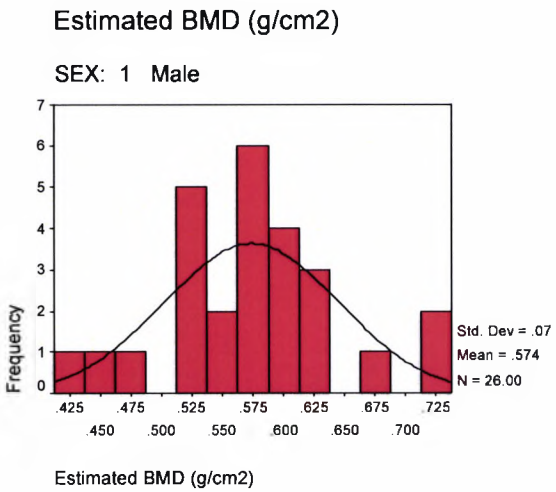


Figure 30 Histogram of male estimated BMD pilot data

The estimated male mean BMD compared to the mean Caucasian female reference of 0.580g/cm^2 in the absence of a male reference was not significantly different.

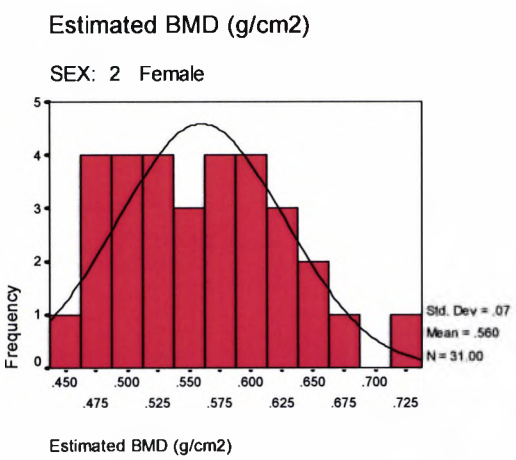


Figure 31 Histogram of female estimated BMD pilot data

The estimated female mean BMD was compared to the mean Caucasian female reference of 0.580g/cm^2 and found to be significantly lower. The primary hypothesis, that Arabic bone strength is lower than Caucasian, is proven for females.

6.2.6 Risk Factors

Baseline data for risk factors are summarized in the following table for males. This table shows how many and what percent of students were in each of the categories assigned for all the risk factors. Assigning the risk factors categories makes it easier to see how many students are at risk in each case.

	Variable (males, n = 26)	*No.*	*%*
	QUS fracture risk		
	Minimal (T-score >0)	23	89
	Moderate (T-score 0 to -1)	3	11
	High (T-score <-1.1)	0	0
1	**BMI kg/m**		
	Underweight (<20)	1	4
	Normal (20-24.99)	12	46
	Overweight (25-29.99)	9	35
	Obese (>30)	4	15
2c	**Level of exercise**		
	Nil	9	35
	Minimal	7	27
	Moderate	10	38
2b	**Number of days exercise done (per week)**		
	None	6	23
	One	5	19
	Three	11	42
	Daily	4	15
3a	**Number of times calcium containing food eaten (per week)**		
	None	11	42
	One	2	8
	Two	3	12
	Daily	10	38
3b	**Number of milk drinks (per week)**		
	None	5	19
	1	4	15
	2	5	19
	7	8	31
	14	2	8
	21+	2	8
4	**Smoker**		
	No	18	69
	Yes	8	31
5	**Number of caffeine containing drinks (per week)**		
	None	2	8
	2	3	11
	7	5	19
	14	7	27
	21+	9	35
6	**Number of carbonated drinks (per week)**		
	None	4	15
	1	3	12
	2	2	8
	7	5	19
	14	7	27
	21+	5	19
9	**Previous Fracture**		
	No	20	77
	Yes	6	23

Table 17 Baseline data from risk factor questions, males

Variable (females, n = 31)		*No.*	*%*
	QUS fracture risk		
	Minimal (T-score >0)	24	77
	Moderate (T-score 0 to -1)	7	23
	High (T-score <-1.1)	0	0
1	**BMI kg/m**		
	Underweight (<20)	7	23
	Normal (20-24.99)	19	61
	Overweight (25-29.99)	4	13
	Obese (>30)	1	3
2c	**Level of exercise**		
	Nil	23	74
	Minimal	5	16
	Moderate	3	10
2b	**Number of days exercise done (per week)**		
	None	15	48
	One	9	29
	Three	4	13
	Daily	3	10
3a	**Number of times calcium containing food eaten (per week)**		
	None	9	29
	One	3	10
	Two	6	19
	Daily	11	36
	Twice daily	2	6
3b	**Number of milk drinks (per week)**		
	None	12	39
	1	5	16
	2	1	3
	7	9	29
	14	3	10
	21+	1	3
4	**Smoker**		
	No	31	100
	Yes	0	0
5	**Number of caffeine containing drinks (per week)**		
	None	6	19
	1	2	7
	2	5	16
	7	9	29
	14	5	16
	21+	4	13
6	**Number of carbonated drinks (per week)**		
	None	19	61
	1	4	13
	2	2	7
	7	6	19
7a	**Menarche prior to age 17**		
	No	1	3
	Yes	30	97
7b	**Regular menstruation**		
	No	9	29
	Yes	22	71
8	**Hands and face fully covered (no sunlight exposure)**		
	No	28	90
	Yes	2	7
9	**Previous Fracture**		
	No	25	81
	Yes	5	16

Table 18 Baseline data from risk factor questions, females

The risk factor tables show risks listed by number as they appeared in the concerned chapter.

6.2.6.1 Comparison of Risks, Males to Females

The next tables compare the risk factors between males and females using the Mann-Whitney U and the Wilcoxon non-parametric tests. This test is done by selecting random pairs of observations from the two groups, calculating the difference between the two observations in each pair and then ranking the differences from the smallest to the largest. The test evaluates the null hypothesis that the medians of the two samples are the same (Pagano, 2000, p308).

Variables	*Males (n=26).*	*Females (n=31)*	*p value*
No. of days per week exercise was done (days)	3	1	0.016
No. of times per week calcium containing food was eaten (times)	2	2	0.376
Number of drinks of milk per week (drinks)	2	1	0.244
Number of carbonated drinks per week (drinks)	7	0	0.001
Number of caffeine containing drinks per week (drinks)	14	7	0.011

Table 19 Comparison of pilot data risk factor medians, male to female

Males performed more exercise and consumed more caffeine and carbonated drinks. Calcium containing food and milk consumption were equal for both groups.

6.2.6.2 Effect of Risk on Bone Strength

In order to assess the effect of risk factors on bone strength, each risk factor was assigned a cut off point to determine the presence or absence of the risk. The cut off points are shown in the next table. Some risk factors were addressed in more than one way, depending on the question wording in the survey instrument. Analysis was performed for each question type for example question 2 a, b, and c, all relate to exercise.

No.	*Variable*	*Criteria for Risk*
1	BMI (kg/m^2)	Underweight (<20)
2a	Physical exercise in the last 7 days	None
2b	Number of days exercise done per week (days)	Three or less
2c	Level of exercise	Nil or minimal exercise
3a	No. of days Ca containing food eaten (per week)	Less than daily (<7)
3b	No. of milk (drinks per week)	Less than two daily (<14)
4	Smoker	Yes
5	No. of caffeine containing drinks (per week)	Daily or more (=7)
6	No. of carbonated drinks (per week)	Twice daily or more (=14)
7a	Age at menarche (years)	Late menarche (>17)
7b	Regular menstruation	No
8	Hands and face fully covered	Yes (no sunlight exposure)
9	Previous fracture	Yes

Table 20 Description of cut off points for assigning risk factor presence

Data which compares the mean QUS est. BMD value in the presence and absence of risk factors is shown in Tables 22 and 23. If in the presence of the risk factor, the mean QUS est. BMD is less than when the risk is not present then a link is shown.

Variable	*Levene's test p value*	*QUS est. BMD with Risk*	*QUS est. BMD with No risk*	*t-test*			*95% C I of diff.*	
				df	*p value*	*mean diff.*	*Lower*	*Upper*
BMI (kg/m^2)	-	-	-	-	-	-	-	-
Exercise	0.198	0.540	0.582	24	0.249	-0.042	-0.114	0.031
Days of exercise	0.424	0.563	0.634	24	0.064	0.071	-0.005	0.147
Level of exercise	0.357	0.547	0.616	24	0.014**	0.068	0.015	0.122
Days Ca	0.445	0.560	0.595	24	0.243	0.034	-0.025	0.093
Milk drinks	0.518	0.567	0.611	24	0.260	0.044	-0.035	0.124
Smoker	0.656	0.584	0.569	24	0.638	0.015	-0.049	0.078
Caffeine drinks	0.999	0.567	0.603	24	0.323	-0.036	-0.109	0.037
Carbonated drinks	0.810	0.565	0.581	24	0.585	-0.016	-0.074	0.043
Fracture	0.019*	0.597	0.567	24	0.554	-0.031	-0.152	0.090

* p value of < 0.05 indicates Levene's test significant, equal variances cannot be assumed

** p value of < 0.05 indicates t-test significant

- indicates test could not be computed because one group did not contain enough subjects

Table 21 Comparison of QUS est. BMD means, by risk factor, males

For every risk except fracture and smoking the mean QUS est. BMD is lower in the presence of the risk factor. Level of exercise risk is the only one which reaches statistical significance.

Variable	*Levene's test p value*	*QUS est. BMD with Risk*	*QUS est. BMD with No risk*	*t-test*			*95% C I of diff.*	
				df	*p value*	*mean diff.*	*Lower*	*Upper*
BMI (kg/m^2)	0.260	0.538	0.567	29	0.338	0.028	-0.031	0.087
Exercise	0.798	0.564	0.557	29	0.778	0.007	-0.043	0.058
Days of exercise	0.425	0.560	0.560	29	1.000	0.000	-0.085	0.085
Level of exercise	0.651	0.561	0.550	29	0.799	-0.011	-0.096	0.074
Days Ca	0.912	0.559	0.561	29	0.933	-0.002	-0.055	0.049
Milk drinks	0.315	0.556	0.586	29	0.427	0.029	-0.045	0.104
Smoker	-	-	-	-	-	-	-	-
Caffeine drinks	0.067	0.568	0.548	29	0.427	0.020	-0.031	0.070
Carbonated drinks	-	-	-	-	-	-	-	-
Late menarche	-	-	-	-	-	-	-	-
Irregular menst.	0.083	0.584	0.550	29	0.206	0.034	-0.020	0.088
No sunlight	0.003*	0.608	0.557	29	0.758	-0.051	-1.604	1.503
Fracture	0.385	0.622	0.548	28	0.026**	-0.074	-0.137	-0.010

* p value of < 0.05 indicates Levene's test significant, equal variances cannot be assumed

** p value of < 0.05 indicates t-test significant

- indicates test could not be computed because one group did not contain enough subjects

Table 22 Comparison of QUS est. BMD means, by risk factor, females

There are no significant differences between the means, except in the case of fracture, but in the opposite direction than expected, i.e. those who had sustained a fracture had higher mean bone strength than those who had not. This may have been due to more sports activity by the group who had fractured or just that they were more active. Cause of fracture was not explored in this pilot study.

6.2.6.3 Correlations

Correlation statistical analysis data, of each risk factor with estimated BMD, are shown for males and females in Tables 23 and 24.

Correlation to QUS est. BMD	*Males*		
Variable	**n**	**ρ**	**p value**
Height (cm)	26	-0.044	0.831
Weight (kg)	26	0.154	0.452
BMI (kg/m^2)	26	0.183	0.372
Exercise Level (none, minimal, moderate)	26	0.343	0.087**
No. of days exercise per week (days)	26	0.445	0.023*
No. of days Ca food per week (days)	26	0.203	0.320
No. of drinks of milk per week (drinks)	26	0.268	0.186
No. of caffeine drinks per week (drinks)	26	-0.148	0.470
No. of carbonated drinks per week (drinks)	26	-0.168	0.413
No of cigarettes per day (cigarettes)	8	-0.093	0.652

* significant at the 0.05 level, 2 sided

** significant at the 0.05 level, 1 sided

Table 23 Correlation of independent variables to QUS est. BMD, males

Correlation to est. BMD	*Females*		
Variable	**n**	**ρ**	**p value**
Height (cm)	31	-0.112	0.550
Weight (kg)	31	0.308	0.091**
BMI (kg/m^2)	31	0.398	0.027*
Exercise Level (none, minimal, moderate)	31	0.124	0.506
No. of days exercise per week (days)	31	-0.063	0.736
No. of days Ca food per week (days)	31	-0.098	0.600
No. of drinks of milk per week (drinks)	31	0.174	0.350
No. of caffeine drinks per week (drinks)	31	0.215	0.246
No. of carbonated drinks per week (drinks)	31	0.279	0.128
No of cigarettes per day (cigarettes)	0	-	-

* significant at the 0.05 level, 2 sided

** significant at the 0.05 level, 1 sided

Table 24 Correlation of independent variables to QUS est. BMD, females

6.3 Full Study

The total number of students who volunteered for the full study and completed both the lifestyle measure and at least one QUS measurement was 337. Because there is no risk from QUS, as was done for the pilot study, all volunteers were accepted on the days of data collection. This avoided any embarrassment for the student which would have resulted from their being turned away in front of their peers. For the same reason, African and Asian students were treated sympathetically and although it was explained that they did not have to fill in the questionnaire, they were still offered a scan whenever possible, subject to time constraints.

6.3.1 Sample

6.3.1.1 Exclusions

On subsequent scrutiny of the questionnaires, some candidates were found to have one of the exclusion criteria and were then removed from the data. The number of cases removed and the reasons are shown in Table 25. Forty one students were excluded for the following reasons: health, age was outside the 18-25 year bracket, severe obesity or an orthopaedic problem.

Condition	No. excluded	
	Females	**Males**
Multiple sclerosis	2	
Hypothyroidism	1	
Epilepsy	1	1
Hypoprolactinaemia	1	
Hyperprolactinaemia	1	
Medicated clinical depression	1	1
Insulin diabetes		1
G6PD* enzyme deficiency	2	1
Asthma	2	3
Severe obesity(BMI >35)	3	6
Age >25	10	3
Previous calcaneal fracture		1
Total	**24**	**17**

*Glucose-6-phosphate dehydrogenase

Table 25 Exclusions

This left a total of 296 students; 120 UOS males, 137 UOS females and 39 DWC females. Initially, all analyses of bone strength results were divided into three sub-sets based on sex and place of study.

The variables of height, weight, BMI and all bone strength readings were box plotted. This gives a visual indication of the spread of the data and shows outliers. Outliers were kept in the study results as they were considered clinically relevant.

6.3.1.2 Sample Size

Sample	Min. no. *	Min. no. **	Min. no. ***	Calcaneal QUS	Phalanges QUS	Hip DXA
Females UOS	96	84	30	120	71	38
Females DWC	96	84	30	33	10	0
Females Total	96	84	30	153	81	38
Males UOS	96	84	30	112	44	31

*based on 80% power calculation (Pagano)
**based on sample size calculation and 5% expected difference (Daniel)
***based on sample size calculation and 9% expected difference (Daniel)

Table 26 Actual sample sizes

The actual sample sizes achieved were high and well exceeded the minimum targets as can be seen in Table 26. The sample sizes from DWC were the smallest because data collection was over two days only, however it was intended that these results would be added to the UOS females rather than standing as a group alone. No DXA scans were offered to DWC females because of time constraints.

6.3.2 Distribution of Data

6.3.2.1 Variables

The full SPSS catalog consisted of 83 variables. Some of these variables were answers to original questions and others were recoded from original variables. Two new variables were calculated for BMI, one from weight divided by the square of height and the second as categories (underweight, normal, overweight, obese). The variable named average QUS was calculated from the left and right calcaneal measurements, also a variable was coded for the

lowest QUS reading for each student.

Up to 3 sports were entered for each volunteer. The variables assigned were sport 1, 2 and 3 from a list of sport types and then the number of units (1 unit = 15 mins) for each. The total number of units of sport per week was added for the variable total sports. This variable did not take into consideration the exertion involved in the sport so a new variable called "total sport new" was created by multiplying the units of sport by a weighting factor which was assigned on a scale with the highest rating for the most energetic sport, see Table 27. These ratings were assigned by the researcher according to whether the sport was individual or team and whether activity would usually be continuous or intermittent.

Sport	Weighting Factor
Weight lifting	4
Soccer	3
Basketball	3
Football	3
Exercises	4
Skating	2
Running	4
Tennis	2
Martial arts	4
Volleyball	3
Gymn	4
Body building	4
Cycling	2
Table tennis	1
Bowling	1
Water skiing	3
Aerobics	4
Wrestling	4
Squash	4
Horse riding	3
Dance	2
Badminton	2

Table 27 Sport Weighting Factor

The IPAQ activity score was calculated from the answers to the IPAQ questions and entered as both a number and an activity category.

Ordinal variables for milk, calcium and caffeine levels were created from the scale variables. Although using scale data is more accurate and yields the best results, often it is desirable to first check for relationships with a few simple groups such as high, moderate and low.

For smokers, the total number of cigarettes was a variable in which the number of cigarettes per day was multiplied by the number of years the person had been smoking. Some students smoked the Arabic Shisha pipe and so a conversion was needed to add this tobacco use to the cigarettes score. One Shisha pipe was estimated to be equivalent to 20 cigarettes although this estimation is imprecise because a Shisha pipe smoking session could be a short or very long time, with the pipe being refilled with fresh tobacco. This information was not questioned in the lifestyle tool or included in the scope of this thesis and estimations had to be accepted.

Finally, in order to perform receiver operator curves and odds ratios, variables were created which assigned the presence or absence of a risk factor, for example low calcium intake or adequate calcium intake.

6.3.2.2 Tests of Normality

The next operation that was performed on the continuous data was to check for normality. This was done by observation of the graphic representation of the data and by using the one sample Kolmogorov-Smirnov test. This procedure compares the distribution for a variable with a specified theoretical distribution, either normal, uniform, Poisson, or exponential. This goodness-of-fit test states whether or not the data has the specified distribution. The results show normality when the value for significance is large. The distribution is not normal if the significance of the test is < 0.05. The continuous variables, height, weight and BMI were normally distributed. In the UOS female group, both weight and BMI were approaching 0.05 and the distributions were right skewed with a predominance of students of lower weight and BMI. The distribution of the QUS parameters and DXA were all normal. The distributions of the risk factors were not normal and they were treated accordingly for statistical analysis.

6.3.3 Representativeness of Sample

6.3.3.1 Age

Reference ranges on the equipment used for QUS calcaneum and DXA hip start at age 20. In order to justify the inclusion of 18 and 19 year olds in the sample i.e. that the group would still be homogenous in terms of bone strength characteristics, t-tests were done on these dependant

variables between the group of 20 years and above and the group of 18 and 19 year olds and then repeated with 18 year olds against the 19 and above category. If the younger students had not yet reached PBM in the anatomical areas tested then they would have lower mean values for bone strength than the older group. This test would be significant if there was a statistical difference in the means of each age group. Reference data is not available for this population therefore the age of PBM was unknown.

6.3.3.1.1 Bone Strength Above and Below 20 Years

Interestingly, a difference was found for both age group comparisons but in the opposite direction. All the measures of calcaneal QUS in the male group were significantly higher for the younger group than the older volunteers. This can be seen in Table 28. Three of the four DXA mean values were also higher although without reaching statistical significance.

	Males under 20	*Males 20 and over*	*p value*
QUS	***(n=38)***	***(n=74)***	
SI lowest calcaneus	101 ± 17	95 ± 14	0.035
SI right calcaneus	105 ± 20	99 ± 17	0.071
SI left calcaneus	105 ± 18	98 ± 14	0.032
SI average calcaneus	105 ± 18	98 ± 15	0.045
DXA	***(n=9)***	***(n=22)***	
total hip (g/cm^2)	1.039 ± 0.123	1.037 ± 0.134	0.960
neck of femur (g/cm^2)	0.905 ± 0.076	0.901 ± 0.111	0.922
trochanter (g/cm^2)	0.786 ± 0.108	0.777 ± 0.108	0.850
intertrochanter (g/cm^2)	1.230 ± 0.162	1.234 ± 0.176	0.958

Table 28 Means of bone strength to age <20 years (UOS males)

	Females under 20	*Females 20 and over*	*p value*
QUS	***(n=46)***	***(n=74)***	
SI lowest calcaneus	93 ± 12	90 ± 11	0.086
SI right calcaneus	96 ± 14	93 ± 13	0.295
SI left calcaneus	96 ± 12	93 ± 13	0.150
SI average calcaneus	96 ± 12	93 ± 12	0.188
DXA	***(n=17)***	***(n=21)***	
total hip (g/cm^2)	0.856 ± 0.138	0.809 ± 0.097	0.231
neck of femur (g/cm^2)	0.761 ± 0.130	0.699 ± 0.092	0.097
trochanter (g/cm^2)	0.636 ± 0.112	0.611 ± 0.110	0.493
intertrochanter (g/cm^2)	1.019 ± 0.160	0.970 ± 0.109	0.268

Table 29 Means of bone strength to age <20 years (UOS females)

	Females under 20	*Females 20 and over*	*p value*
QUS	***(n=13)***	***(n=20)***	
SI lowest calcaneus	93 ± 12	92 ± 15	0.838
SI right calcaneus	100 ± 17	98 ± 17	0.789
SI left calcaneus	95 ± 14	94 ± 15	0.772
SI average calcaneus	98 ± 15	96 ± 15	0.780

Table 30 Means of bone strength to age <20 years (DWC females)

6.3.3.1.2 Bone Strength Above and Below 19 Years

	Males under 19	*Males 19 and over*	*p value*
QUS	***(n=17)***	***(n=95)***	
SI lowest calcaneus	101 ± 20	96 ± 14	0.189
SI right calcaneus	107 ± 23	100 ± 17	0.152
SI left calcaneus	106 ± 19	99 ± 15	0.125
SI average calcaneus	106 ± 20	100 ± 15	0.130
DXA	***(n=2)***	***(n=29)***	
total hip (g/cm^2)	1.039 ± 0.172	1.037 ± 0.130	0.990
neck of femur (g/cm^2)	0.930 ± 0.072	0.900 ± 0.103	0.695
trochanter (g/cm^2)	0.787 ± 0.112	0.779 ± 0.108	0.923
intertrochanter (g/cm^2)	1.226 ± 0.268	1.233 ± 0.166	0.952

Table 31 Means of bone strength to age <19 years (UOS males)

	Females under 19	*Females 19 and over*	*p value*
QUS	***(n=20)***	***(n=100)***	
SI lowest calcaneus	93 ± 11	91 ± 12	0.362
SI right calcaneus	96 ± 13	94 ± 13	0.517
SI left calcaneus	97 ± 12	94 ± 13	0.305
SI average calcaneus	97 ± 12	94 ± 12	0.376
DXA	***(n=9)***	***(n=29)***	
total hip (g/cm^2)	0.892 ± 0.157	0.811 ± 0.099	0.072
neck of femur (g/cm^2)	0.776 ± 0.144	0.712 ± 0.100	0.135
trochanter (g/cm^2)	0.665 ± 0.123	0.609 ± 0.104	0.183
intertrochanter (g/cm^2)	1.071 ± 0.178	0.967 ± 0.111	0.041

Table 32 Means of bone strength to age <19 years (UOS females)

	Females under 19	*Females 19 and over*	*p value*
QUS	***(n=5)***	***(n=28)***	
SI lowest calcaneus	98 ± 10	92 ± 14	0.364
SI right calcaneus	102 ± 10	98 ± 17	0.719
SI left calcaneus	101 ± 12	93 ± 15	0.295
SI average calcaneus	102 ± 11	96 ± 15	0.468

Table 33 Means of bone strength to age <19 years (DWC females)

Having noted that bone strength for either the 18 and 19 year olds or just the 18 year olds appeared higher rather than lower than older subjects, it was decided to follow this up by looking at all ages. This procedure is similar to that for building a reference curve for a population however that had not been one of the objectives for this study. Building a reference curve requires a strict policy to be adhered to and larger numbers than available here. However, by looking at the mean bone strength value for each age group an impression could be formed of the progress of bone strength through this range of ages. The following data presents the number of cases in each age category and beside that the box plot of mean bone strength for each age group. The data is presented for each group, males and females.

The results shown here are for all bone strength measures. There are three measures of calcaneal QUS; 1/ the lowest reading, 2/ the right heel stiffness and 3/ the left heel stiffness.

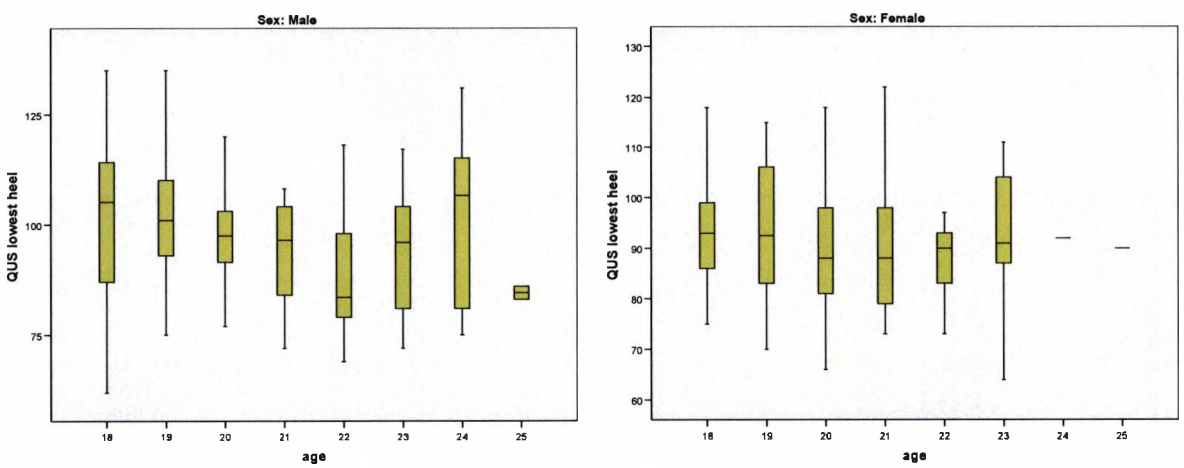


Figure 32 Box plot of QUS lowest heel by age

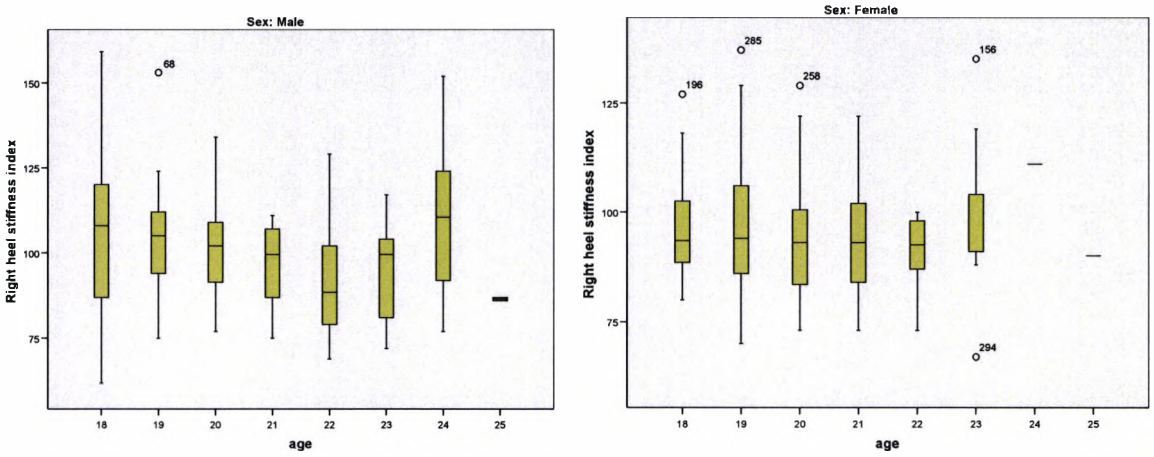


Figure 33 Box plot of QUS right heel by age

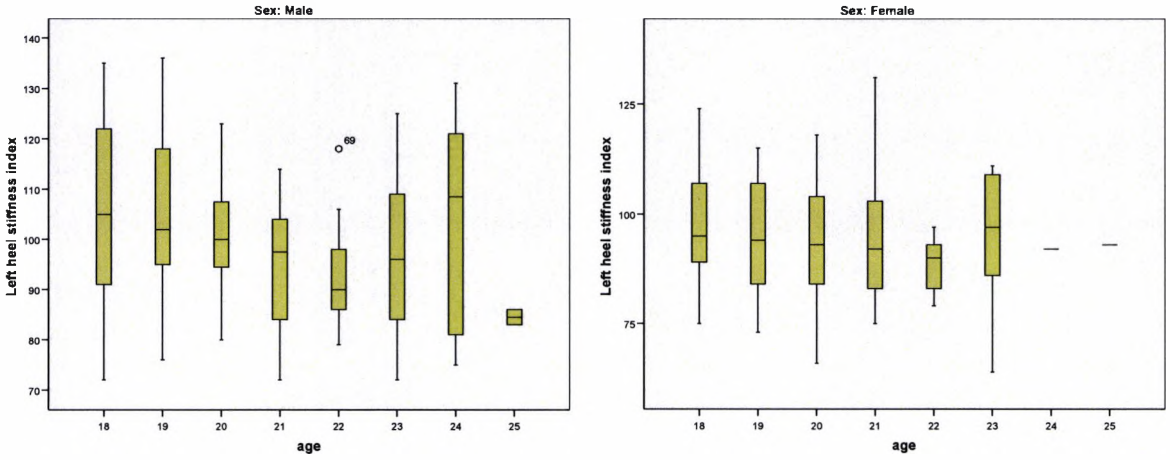


Figure 34 Box plot of QUS left heel by age

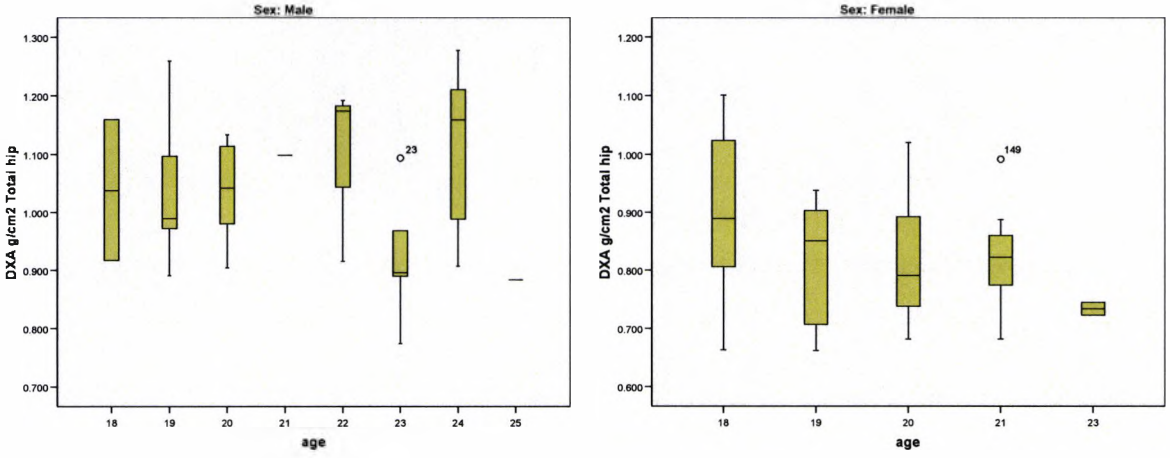


Figure 35 Box plot of DXA Total Hip (g/cm^2) by age

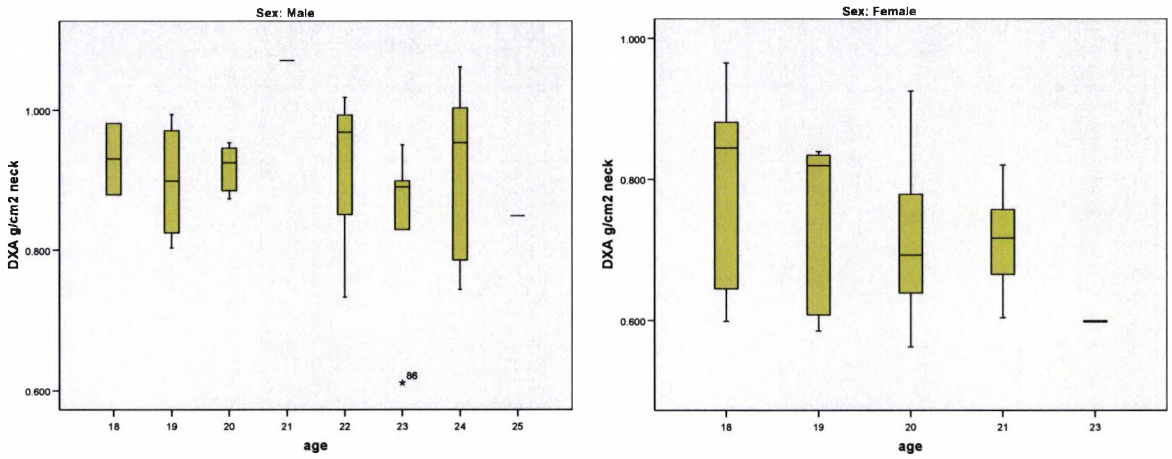


Figure 36 Box plot of DXA neck (g/cm^2) by age

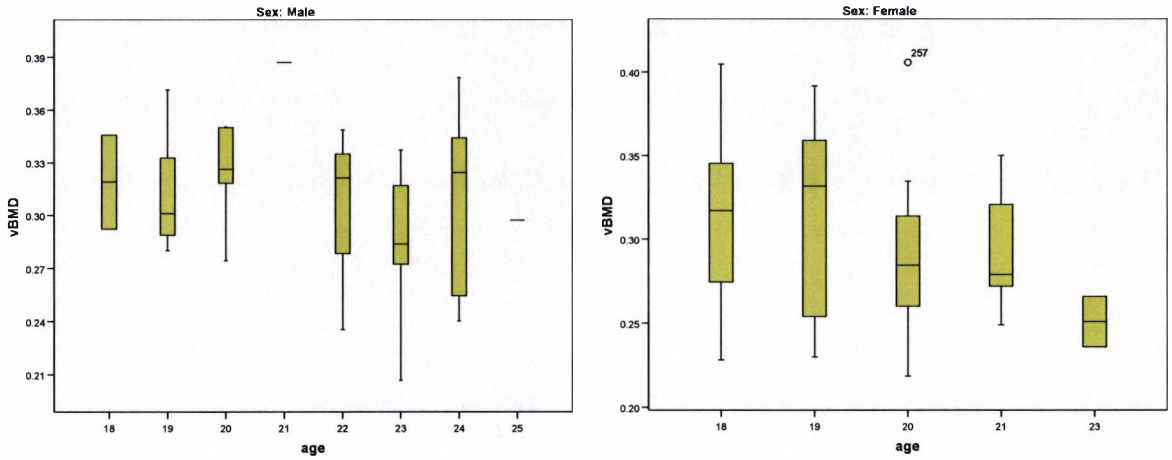


Figure 37 Box plot of vBMD neck (g/cm^3) by age

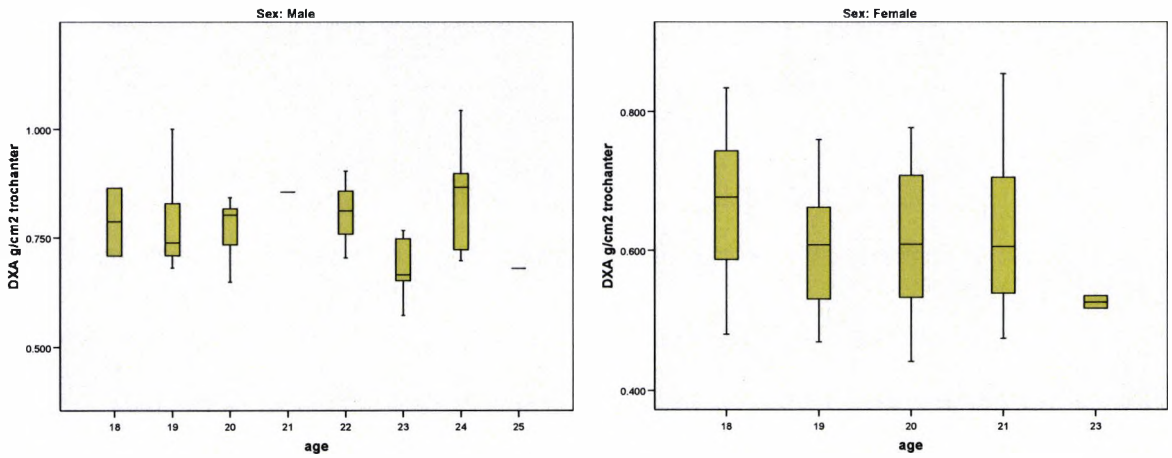


Figure 38 Box plot of DXA trochanter (g/cm^2) by age

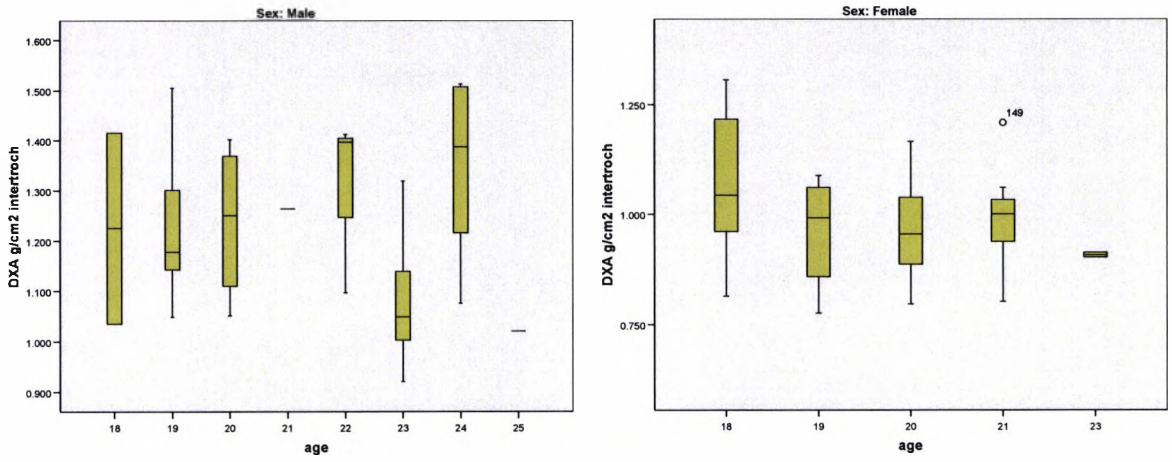


Figure 39 Box plot of DXA intertrochanter (g/cm^2) by age

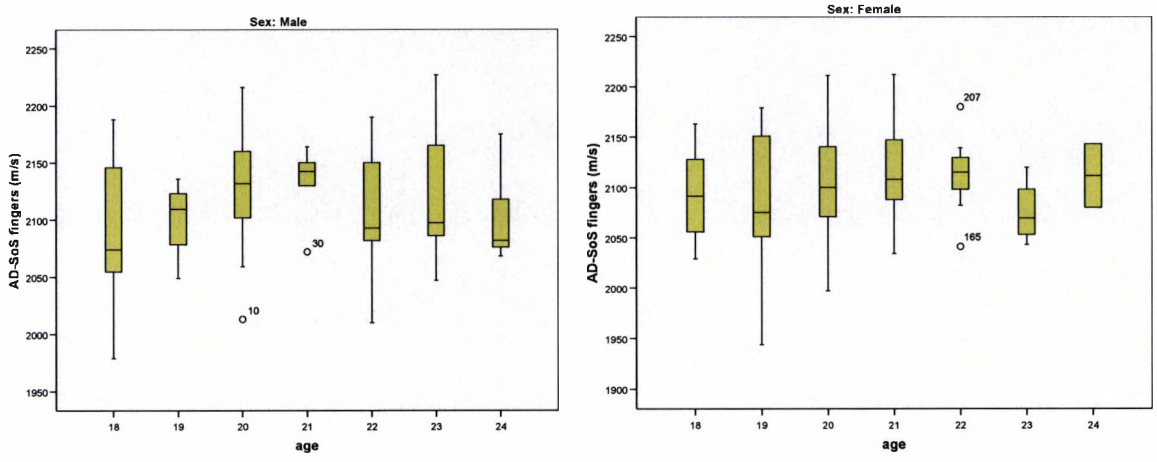


Figure 40 Box plot of QUS Ad SOS phalanges (m/sec) by age

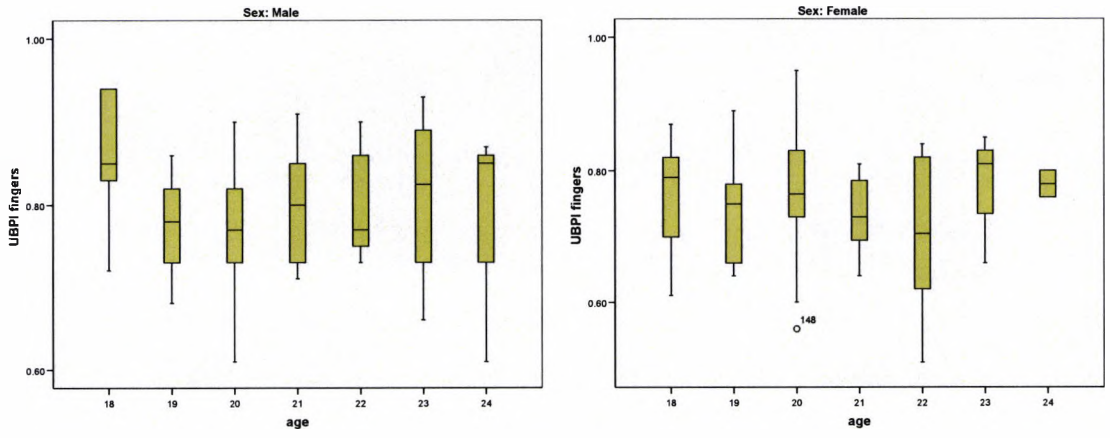


Figure 41 Box plot of QUS UBPI phalanges by age

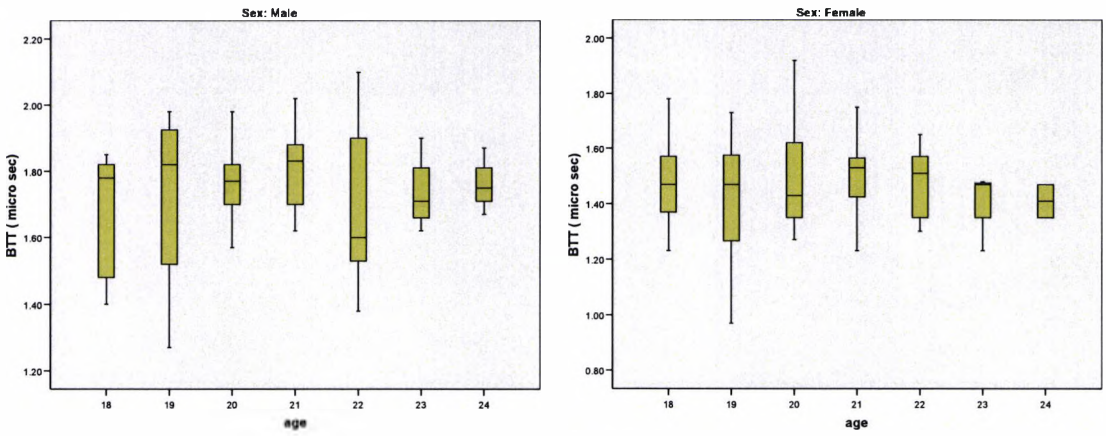


Figure 42 Box plot of QUS BTT phalanges (dB/MHz) by age

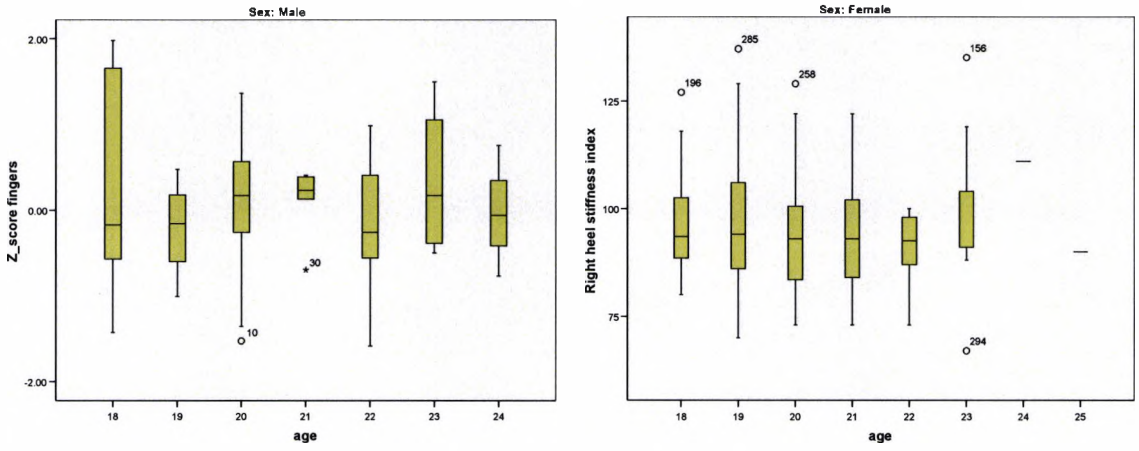


Figure 43 Box plot of QUS Z-score phalanges (SD) by age

These results give a visual representation of the variation in bone strength as measured year by year. It can be seen that the average readings for the 18 or 19 year olds is always higher than the 20 year old group for QUS of the calcaneum. In some of the older age groups the number in the sample is very small and those results should be treated with caution but clearly the 18 and 19 year olds do not appear to have lower bone strength than the 20 and 21 year olds which justifies keeping them in the sample for future analysis.

To be sure that there is no difference between the different age groups for QUS, t-tests were performed. These are shown in appendix C. The test used was Anova with Bonferroni correction to take into account that there are more than two groups. As an example, if there are three groups instead of two then the Bonferroni correction divides the usual required

significance of 0.05 by 3 which means that the significance would have to be 0.0167 to prove the test. The results for the groups with higher numbers are the important ones as some age groups have 1 or only a small number of students and cannot therefore be relied on in this test. However, the important results are that there are no significant differences between any of the groups with at least 5 students.

It is possible that the 18 and 19 year olds could have differed from the over 20 year olds in some other way which caused them to have a falsely high set of bone strength data. The areas of prime concern are the independent factors which most influence bone strength; BMI, exercise and calcium intake. In order to check for any difference between the under and over 20 year olds for these variables, t-tests were performed. Although the test statistics have not been shown here, no statistically significant difference was found between any of the variables tested except for the under 20 year old UOS females, whose calcium intake ($p = 0.017$) was lower. This would have affected the bone strength in the opposite direction to that which was found, i.e. the bone strength might be expected to be lower but was in fact higher. Therefore, all ages can be considered to have similar characteristics for the variables tested here. Other risk factors play a less significant role and have not been tested.

6.3.3.2 Nationality

Having decided that all age categories could be considered together the next independent variable to be explored was the nationality of the students. As mentioned previously, it was stated in the introduction that all Arabs would be considered together because their origins are from across the Arab world and because they have mostly lived in the same environment together and thus been exposed to the same cultural, physical and nutritional background.

Although there is great variety in the country of birth and the nationality of the students, by looking at the domicile (place lived in the longest) it is clear that for the majority of their upbringing has predominantly been in the UAE.

6.3.3.2.1 Country of Birth

The countries of birth of the UOS males, UOS females and all females are shown as pie charts based on percentages. Half the males were born in the UAE, the others were born in 21 different countries around the world.

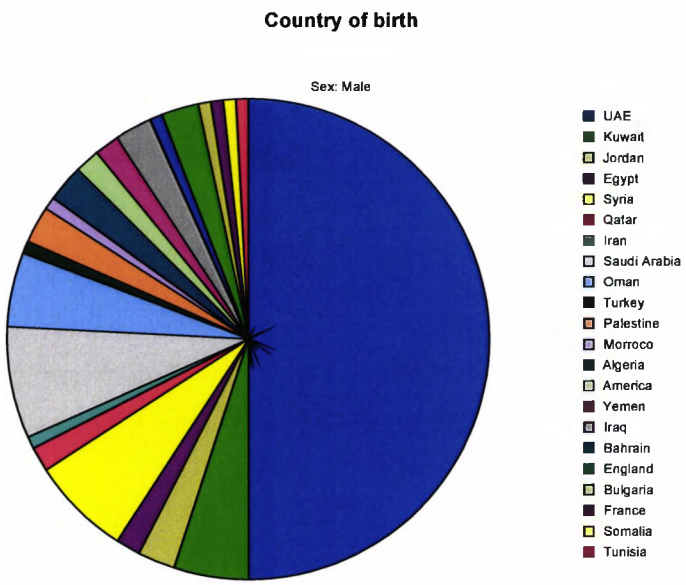


Figure 44 Country of birth, males

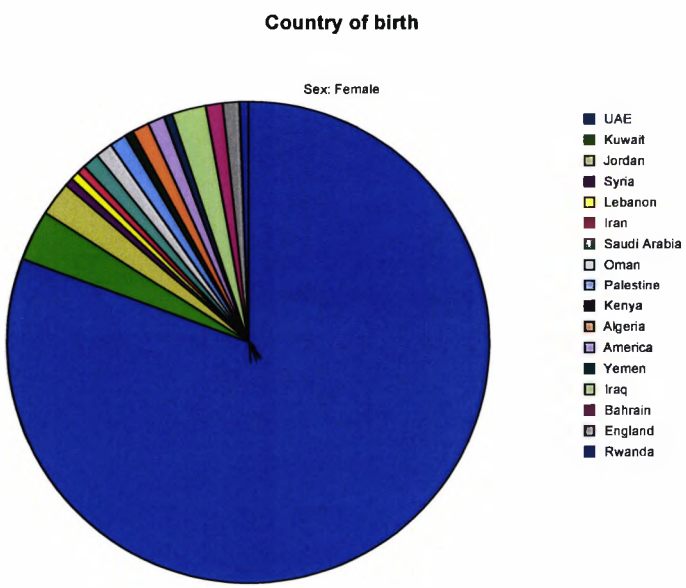


Figure 45 Country of birth, UOS females

A high percentage of the female UOS students were born in the UAE with the remainder

spread across 16 countries worldwide. The pie chart for the DWC females is not shown as all but 1 of them was born in the UAE.

6.3.3.2.2 Domicile

Almost three quarters of the males have lived most of their lives in the UAE. The remainder has lived in 12 other countries but almost all Arab countries, particularly Saudi Arabia and Oman.

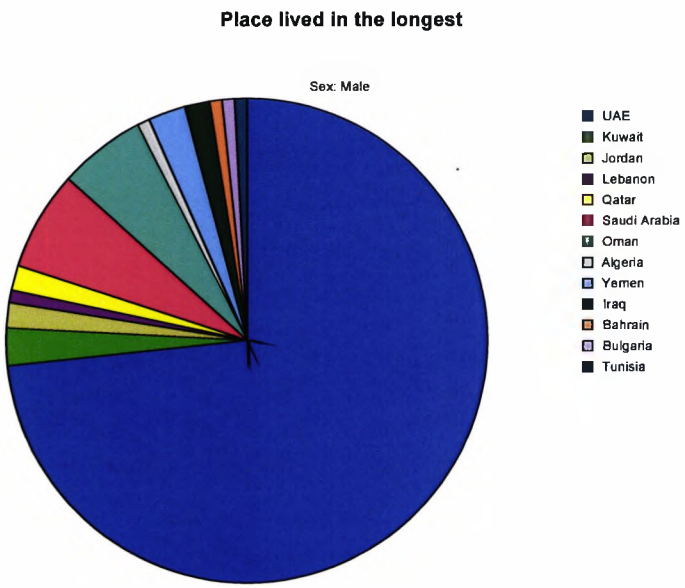


Figure 46 Domicile, males

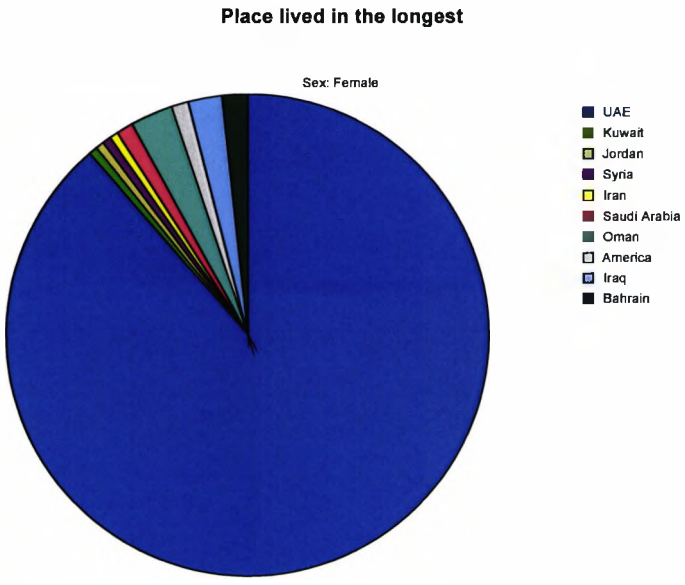


Figure 47 Domicile, all females

The females, UOS and DWC together, have almost all lived most of their lives in the UAE.

Those that have not have almost all been living in neighbouring Arab countries. A higher number of females reside in the UAE as it is a cultural norm for females to be kept at home whereas males are allowed more freedom of movement.

6.3.3.2.3 Nationality

The nationalities of the students are far more diverse than either their county of birth or their domicile. Only a quarter of the males are of UAE nationality.

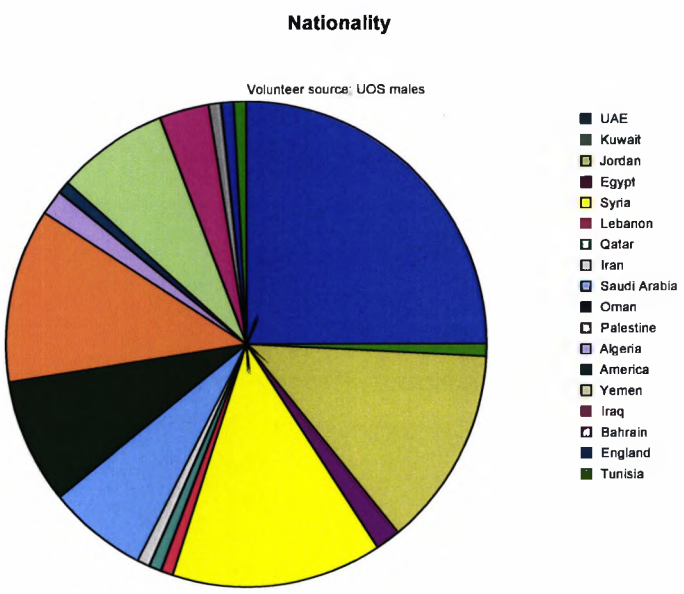


Figure 48 Nationality, males

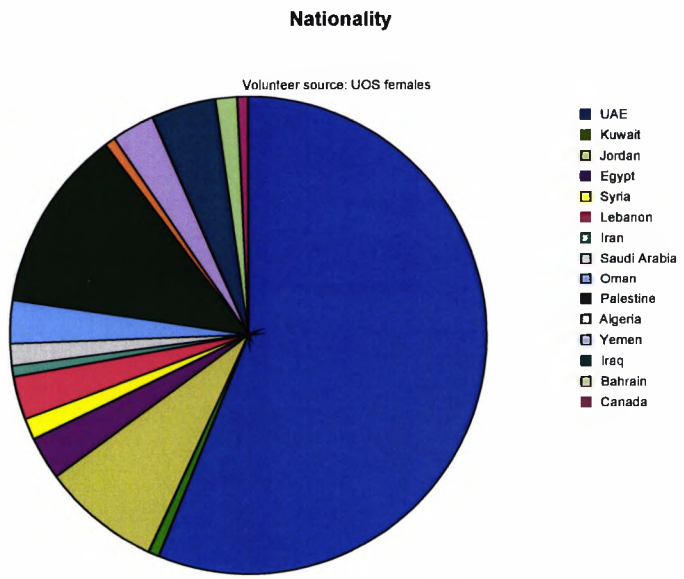


Figure 49 Nationality, UOS females

More than half of the UOS females are UAE nationals. Looking at the group of all females (all of the DWC females are nationals) it can be seen that more than sixty per cent are UAE nationals.

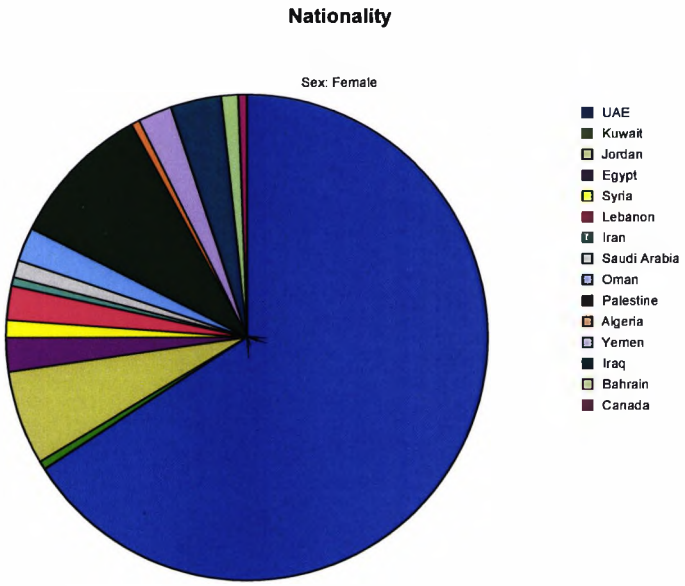
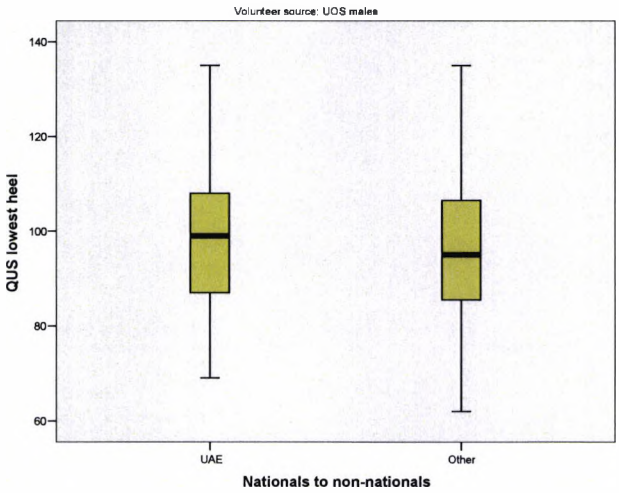


Figure 50 Nationality, all females

6.3.3.2.4 Bone Strength by Nationality

In order to be sure that there was not a vast difference between the bone strength of different nationalities, box plots were produced comparing national to non-national Arabs. Nationals formed the biggest groups in each of the samples whereas the other groups were many but with very small numbers in each which precluded assessments for each of the other nationalities individually. Box plots are shown for QUS calcaneal results for UOS males, UOS females, DWC females and all females. The mean values of each group are very similar in all cases.

Figure 51 QUS SI lowest heel national/non-national, males

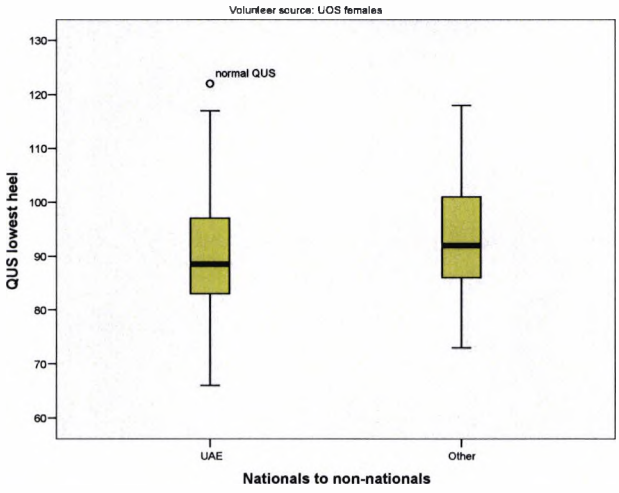


Case Processing Summary[a]

		Cases
	Nationals to non-nationals	Valid N
QUS lowest heel	UAE	29
	Other	83

a. Volunteer source = UOS males

Figure 52 QUS SI lowest heel national/non-national, UOS females

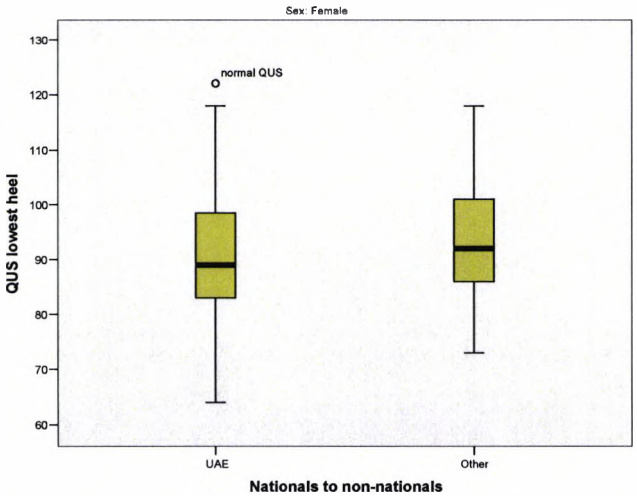


Case Processing Summary[a]

		Cases
	Nationals to non-nationals	Valid N
QUS lowest heel	UAE	70
	Other	50

a. Volunteer source = UOS females

Figure 53 QUS SI lowest heel national/non-national, all females



Case Processing Summary[a]

		Cases
	Nationals to non-nationals	Valid N
QUS lowest heel	UAE	103
	Other	50

a. Sex = Female

To be certain that no differences existed, t-tests were done. Comparing the 29 UAE national males to the 83 non-nationals, there was no significant difference between the mean QUS value ($p = 0.357$). The same was true for the females ($p = 0.149$). The QUS lowest heel value was used for this comparison as an indicator of all bone strength values. In each comparison there was a difference in mean stiffness of 3 units. The UAE males were higher than the other males but the UAE females were lower than the other group of females. This disparity tends to suggest that it is simply random variation because it is not consistant. If there was a genetic reason for the UAE to differ from other Arabs it would presumably be apparent in both males and females.

6.3.3.3 College

To reduce bias, it was intended that students studying in Arabic be represented fairly and that this could be checked by assessing the numbers of students from each college.

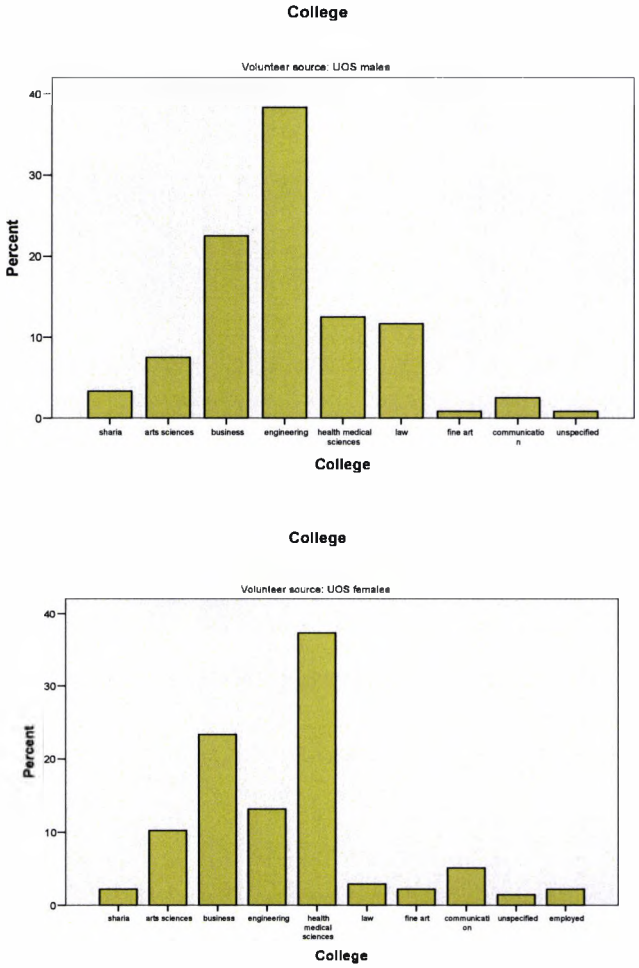


Figure 54 Percent of students in each college, males and females

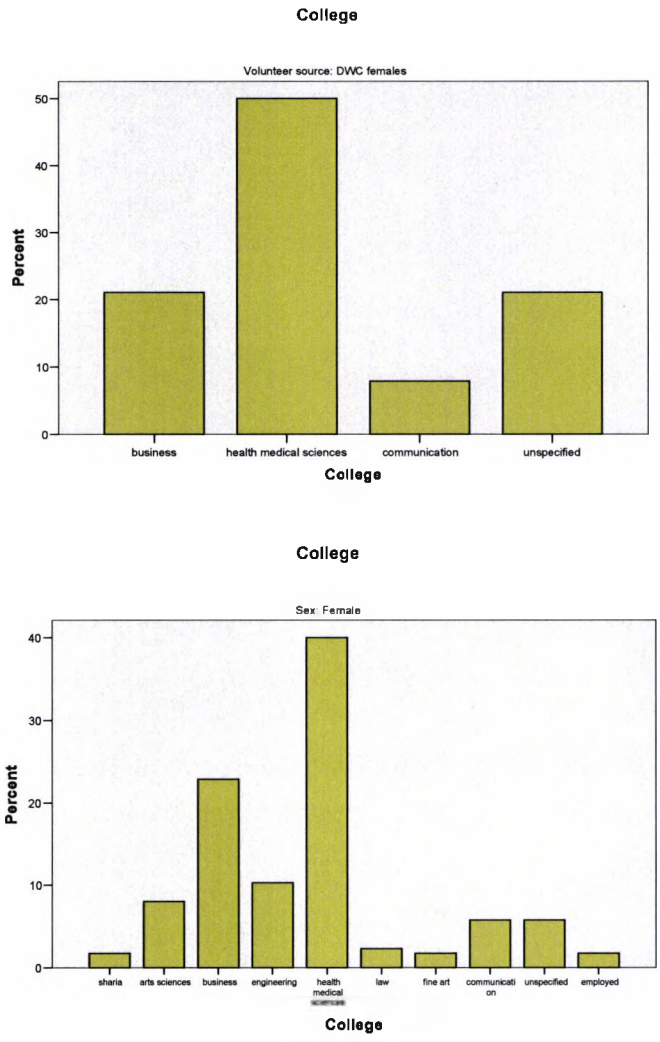


Figure 55 Percent of students in each college, DWC and all females

The distribution of students by college reflected the student enrollment.

In each of these four bar charts, no college exceeds 50% of the overall sample. The distribution of students by college follows the number of students enrolled in each of these colleges at the university, with more boys studying engineering than anything else and more girls the health sciences. The colleges where Arabic language is used for tuition are Sharia, Law and some majors in Arts and Sciences. Unspecified means that the student is still in the intensive English program prior to being registered in their major, and English speaking ability is weak. All these areas are represented in the sample.

6.3.3.4 Academic Institution

Samples were collected from two sites for females, the UOS and DWC. In order to decide whether the two samples could be added together to form one group of all females some

analysis of their characteristics was required. To check whether the two groups of females differed in any way, t-tests or Mann-Whitney tests were done.

	Females UOS	*Females DWC*	*p value*
Variable			
Height (cm)	161.3 ± 5.8	157.6 ± 6.0	0.001
Weight (kg)	59.4 ± 11.5	56.1 ± 11.2	0.113
BMI (kg/m^2)	22.8 ± 3.9	22.6 ± 4.3	0.782
SI lowest calcaneus	91 ± 12	93 ± 14	0.468
SI right calcaneus	94 ±13	99 ±17	0.119
SI left calcaneus	94 ± 13	95 ± 14	0.918
SI average calcaneus	94 ± 12	97 ± 15	0.373
AD-SOS phalanges (m/s)	2,103.9 ± 51.3	2,081.0 ± 59.1	0.199
UBPI phalanges	0.755 ± 0.084	0.703 ± 0.076	0.087
BTT phalanges (microsec)	1.471 ± 0.179	1.472 ± 0.098	0.977
Z-score phalanges (SD)	-0.008 ± 1.142	-0.069 ± 0.889	0.878

Table 34 T-tests variables, UOS to DWC females

Height differed but weight and BMI were the same between groups. No difference between groups for QUS heel. No difference between groups for QUS phalanges. The final comparison of the two groups of females was between risk factors. Although calcium intake ($p = 0.594$) and sun exposure ($p = 0.098$) was the same for each group, IPAQ ($p = 0.028$) and sports activity ($p = 0.005$) differed between students from the two institutions.

6.3.4 Subject Characteristics

Descriptive statistics are presented for age, height, weight and BMI together. The second block of results in this section shows all the descriptive statistics for the dependant variables and the last block shows the descriptive statistics of the independent variables or risk factors.

6.3.4.1 Descriptive Statistics for Demographics and Bone Strength

Variables	*Males*	*Females UOS*	*Females DWC*	*Females all*
Age (years)	20.6 (18-25)	20.1 (18-25)	20.0 (18-24)	20.1 (18-25)
Height (cm)	175.4 ± 7.1	161.3 ± 5.8	157.6 ± 6.0	160. ± 6.1
Weight (kg)	75.9 ± 14.3	59.4 ± 11.5	56.1 ± 11.2	58.6 ± 11.5
BMI (kg/m^2)	24.6± 4.0	22.7 ± 3.8	22.6 ± 4.3	22.7 ± 4.0
SI lowest calcaneus	96.9 ± 15.3	91.1 ± 11.6	92.9 ± 13.5	91.5 ± 12.0
SI right calcaneus	100.9 ± 18.0	94.2 ± 13.3	98.6 ± 16.7	95.2 ± 14.1
SI left calcaneus	100.3 ± 16.0	94.3 ± 12.9	94.6 ± 14.3	94.3 ± 13.2
SI average calcaneus	100.7 ± 16.3	94.3 ± 12.4	96.7 ± 15.0	94.8 ± 12.9
T-score left calcaneus	0.0 ± 1.0*	-0.44 ± 0.9	-0.42 ± 1.1	-0.44 ± 1.0
T-score right calcaneus	0.0 ± 1.0*	-0.44 ± 1.0	-0.11 ± 1.3	-0.37 ± 1.1
total hip (g/cm^2)	1.037 ± 0.129	0.830 ± 0.118		0.830 ± 0.118
neck of femur (g/cm^2)	0.902 ± 0.101	0.727 ± 0.113		0.727 ± 0.113
trochanter (g/cm^2)	0.780 ± 0.106	0.622 ± 0.110		0.622 ± 0.110
intertrochanter (g/cm^2)	1.233 ± 0.170	0.992 ± 0.135		0.992 ± 0.135
T-score total hip	0.029 ± 0.851	-0.918 ± 0.961		-0.918 ± 0.961
T-score neck of femur	-0.197 ± 0.733	-1.105 ± 1.020		-1.105 ± 1.020
T-score trochanter	0.019 ± 0.844	-0.871 ± 1.026		-0.871 ± 1.026
T-score intertrochanter	0.210 ± 0.943	-0.700 ± 0.864		-0.700 ± 0.864
neck of femur width (mm)	37.0 ± 0.23	31.0 ± 0.23		31.0 ± 0.23
neck of femur BMC (g)	4.99 ± 0.57	3.38 ± 0.62		3.38 ± 0.62
vBMD (g/cm^3)	0.311 ± 0.043	0.299 ± 0.050		0.299 ± 0.050
AD-SOS phalanges (m/s)	2,111.1 ± 55.3	2,103.9 ± 51.3	2,081.0 ± 59.1	2,101.0 ± 52.5
UBPI phalanges	0.796 ± 0.089	0.755 ± 0.084	0.703 ± 0.076	0.748 ± 0.084
BTT (µs)	1.74 ± 0.19	1.47 ± 0.18	1.47 ± 0.10	1.47 ± 0.17
T-score phalanges	-0.07 ± 0.77	-0.30 ± 0.75	-0.40 ± 0.52	-0.31 ± 0.72
Z-score phalaanges	0.04 ± 0.89	-0.01 ± 1.14	-0.07 ± 0.89	-0.15 ± 1.11

Table 35 Demographic and Bone Strength Variables by Group

6.3.4.2 Descriptive Statistics for Risk Factors

Variables	*Males*	*Females UOS*	*Females DWC*	*Females all*
Sport 1 (units)	8 (0-140)	0 (0-48)	2 (0-20)	0 (0-48)
Sport 2 (units)	0 (0-40)	0 (0-18)	0 (0-10)	0 (0-18)
Sport 3 (units)	0 (0-36)	0 (0-16)	0 (0-1)	0 (0-16)
Number of sports done	1 (0-3)	0 (0-3)	1 (0-3)	0 (0-3)
Total units sport per week	12 (0-140)	0 (0-50)	2 (0-20)	0 (0-50)
Total sports new	34 (0-420)	0 (0-196)	8 (0-72)	0 (0-196)
IPAQ score	1,986 (0-10,626)	1,181 (0-9,972)	1,866 (0-6,970)	1386 (0-9,972)
Milk drinks per week	2 (0-21)	1 (0-14)	3 (0-21)	2 (0-21)
Calcium intake per day (g)	647 (25-2,725)	465 (0-2,700)	575 (0-1,625)	513 (0-2,700)
Time smoked (yrs)	0 (0-10)	0 (0-3)	0 (0-1)	0 (0-3)
Cigarettes per day	0 (0-40)	0 (0-7)	0 (0-1)	0 (0-7)
Cigarettes total (x1,000 cigs)	0 (0-110)	0 (0-5)	0 (0-0.4)	0 (0-5)
Caffeine per week (mg)	882 (0-5,115)	405 (0-3,338)	443 (0-2,486)	410 (0-3,338)
Carbonated drinks per week	7 (0-90)	3 (0-42)	1 (0-15)	2 (0-42)
Sun exposure per day (mins)	60 (2-360)	30 (0-420)	15 (0-240)	30 (0-420)
Number broken bones	0 (0-6)	0 (0-3)	0 (0-2)	0 (0-3)

Table 36 Risk factor variables by group

6.3.5 Bone Strength Results

The research project was successful in demonstrating that all Arab females have significantly lower bone strength measurements than their Caucasian counterparts. Males have the same mean BMD by DXA as Caucasians.

This section will display the results of all bone strength measurements. For each measurement device there are more than one set of results. Each of these results is available for UOS males, UOS females, DWC females and all females. The results are displayed in the order of QUS calcaneum, QUS phalanges and then DXA hip. MRI is not included here as there are only images available. These will be shown in a later section. Only a selection of the results is shown.

6.3.5.1 Calcaneal QUS Lowest Heel, Males

The histogram is shown for QUS SI lowest heel values for males.

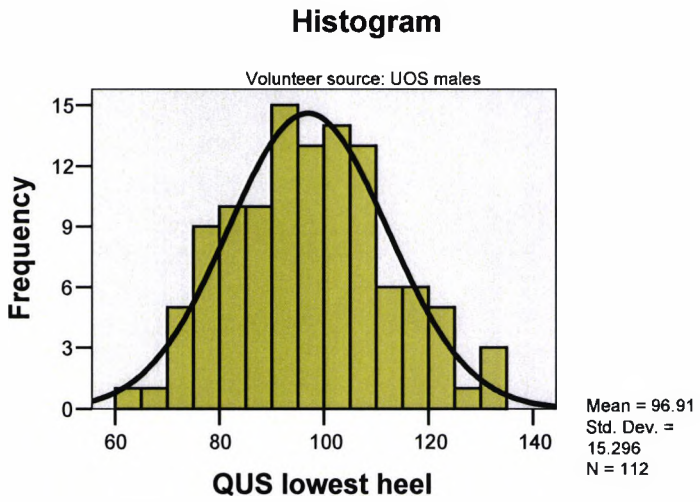


Figure 56 QUS SI lowest heel (UOS males)

6.3.5.2 Calcaneal QUS Lowest Heel, UOS Females

The histogram is shown for QUS SI lowest heel values for UOS females.

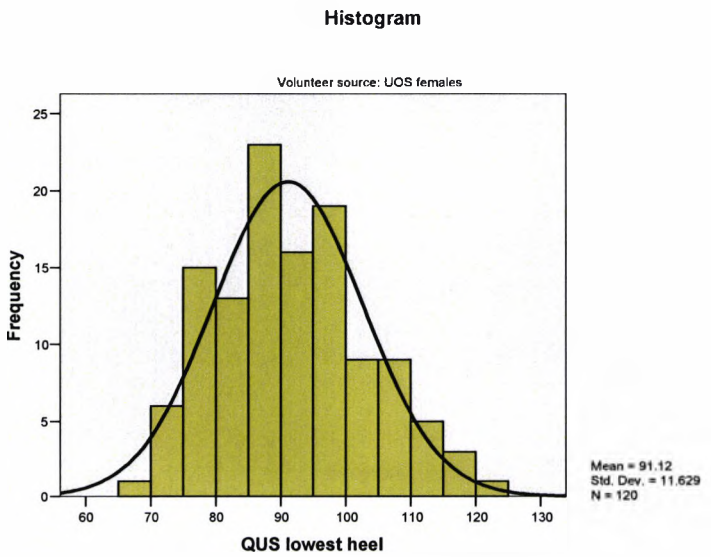


Figure 57 QUS SI lowest heel (UOS females)

6.3.5.3 Calcaneal QUS Lowest Heel, DWC Females

The histogram is shown for QUS lowest heel values for DWC females.

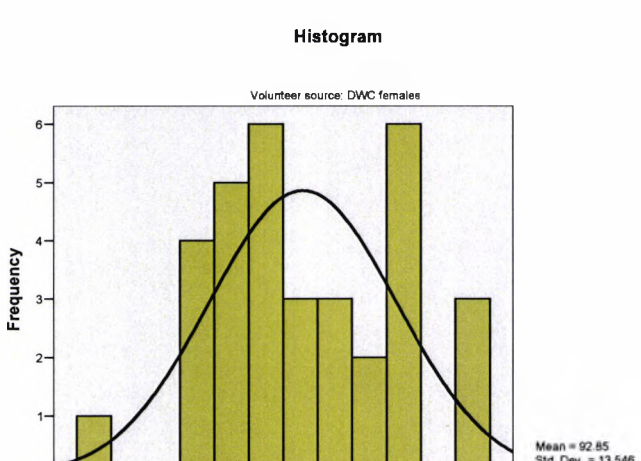


Figure 58 QUS SI lowest heel (DWC females)

6.3.5.4 Calcaneal QUS Lowest Heel, all Females

The histogram is shown for QUS lowest heel values for all females.

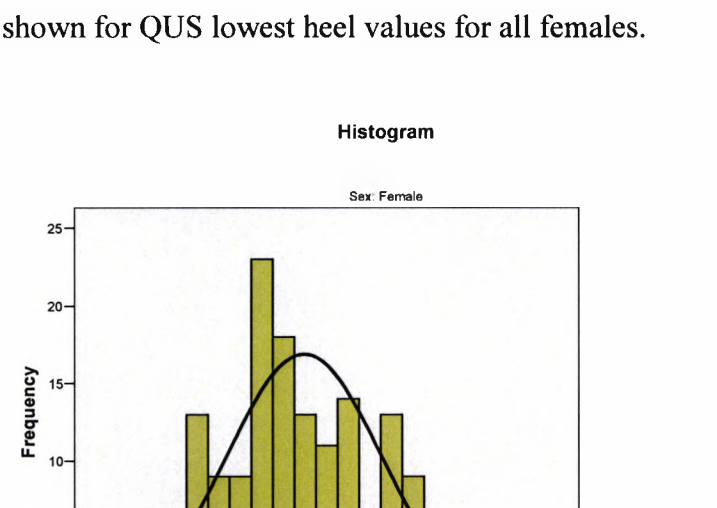


Figure 59 QUS SI lowest heel (all females)

6.3.5.5 Calcaneal QUS Left Heel, Males

The histogram is shown for QUS left heel values for males.

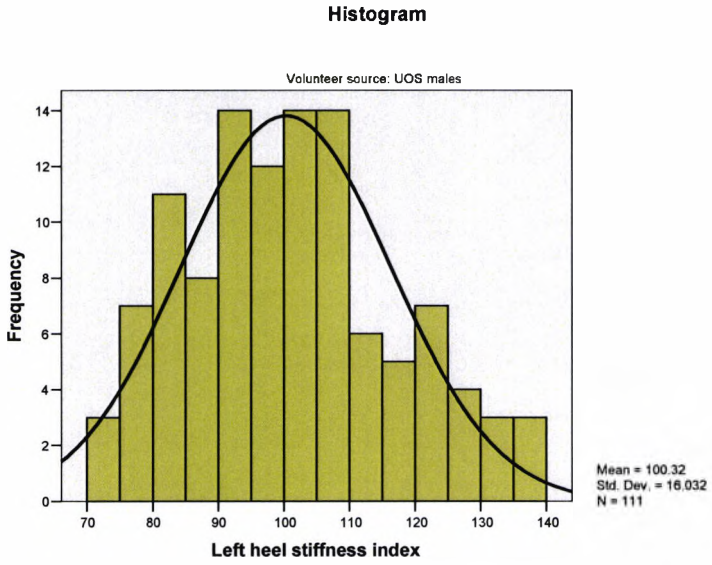


Figure 60 QUS SI lowest heel (UOS males)

6.3.5.6 Calcaneal QUS Left Heel, all Females

The histogram is shown for QUS left heel values for all females. The separate groups of UOS and DWC females are not shown as they were very similar for this reading; UOS females mean was 94.28 (SD 12.949), DWC females mean was 94.55 (SD 14.283).

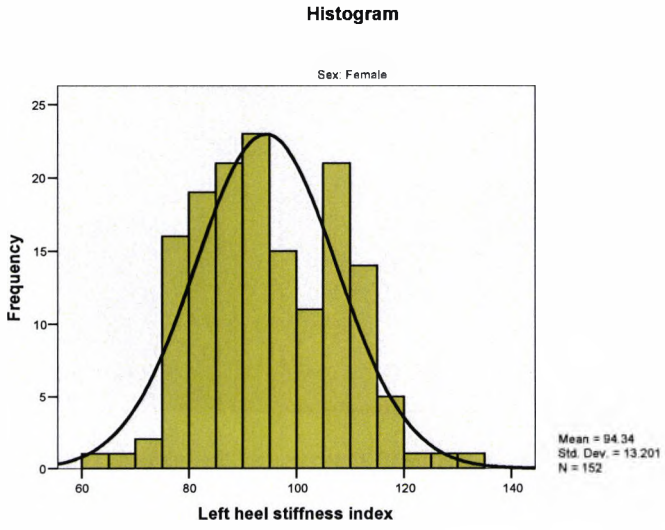


Figure 61 QUS SI left heel (all females)

6.3.5.7 Prevalence of Osteopaenia Based on Caucasian Reference, all Females

The following bar graph shows the percentage of female students with low or normal bone density measured by QUS SI lowest calcaneum of the heel, when the Caucasian reference is

used 34% are classified with low bone strength, osteopaenic.

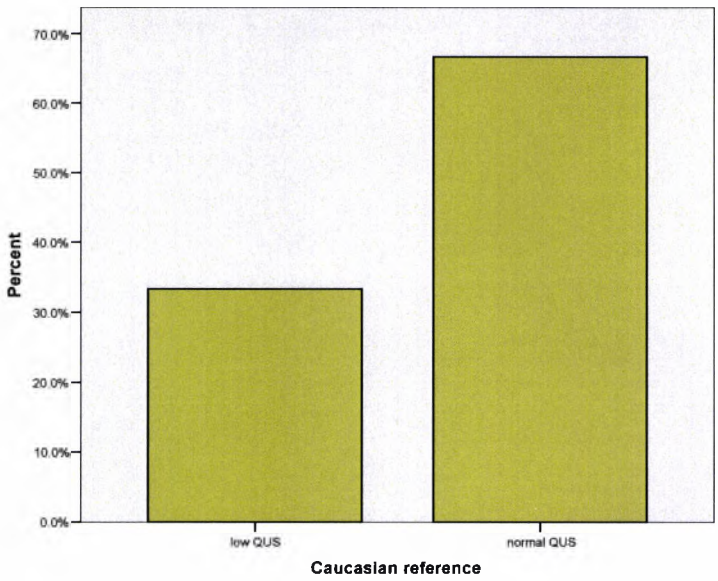


Figure 62 Prevalence of osteopaenia, females, QUS to Caucasian data

Two female students had measurements for QUS SI lowest calcaneum which were classified as osteoporotic, although this is not diagnostic as this equipment cannot be used as such. The definition only applies clinically to a DXA result. These students are not shown on the above bar graph. They were both very low BMIs, one of them 16 and the other 18.

6.3.5.8 Prevalence of Osteopaenia Based on UAE Reference, all Females

The following bar graph shows the percentage of female students with low or normal bone density measured by QUS SI left calcaneum when the UAE reference is used. Now the number is halved with only 17% classified as low bone strength, osteopaenic.

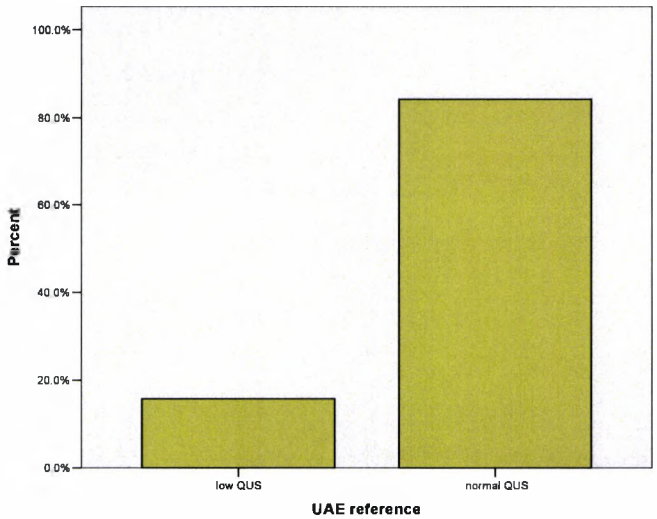


Figure 63 Prevalence of osteopaenia, females, QUS to UAE data

6.3.5.9 Prevalence of Osteopaenia Based on UAE Reference, all Males

The following bar graph shows the percentage of male students with low or normal bone density measured by QUS SI left calcaneum when the UAE reference is used. 18% are classified as low bone strength, osteopaenic.

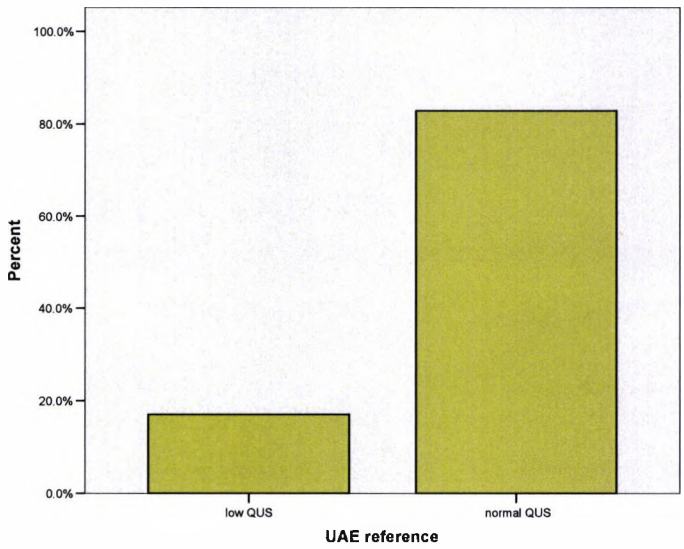


Figure 64 Prevalence of osteopaenia, males, QUS to UAE ref.

6.3.5.10 Phalangeal QUS, Males

The histogram is shown for QUS phalanges Z-score.

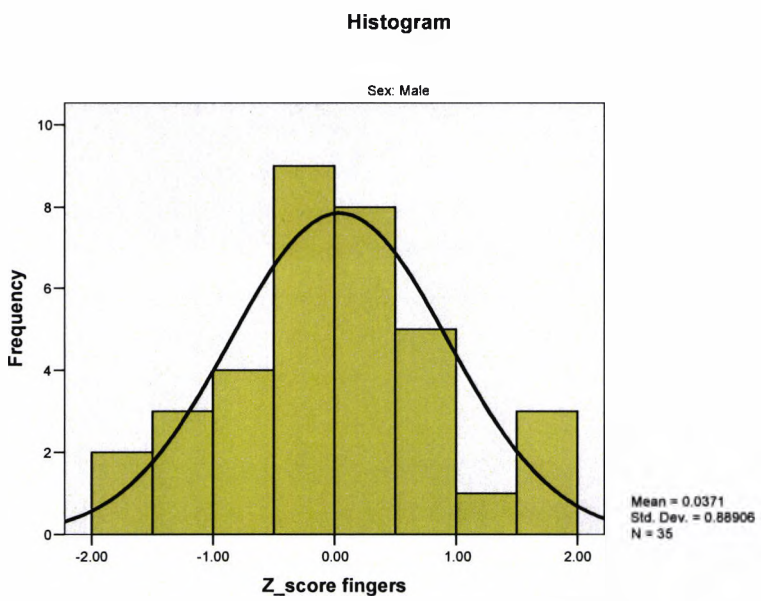


Figure 65 Phalangeal QUS Z-score (UOS males)

6.3.5.11 Phalangeal QUS, UOS Females

The histogram is shown for QUS phalanges.

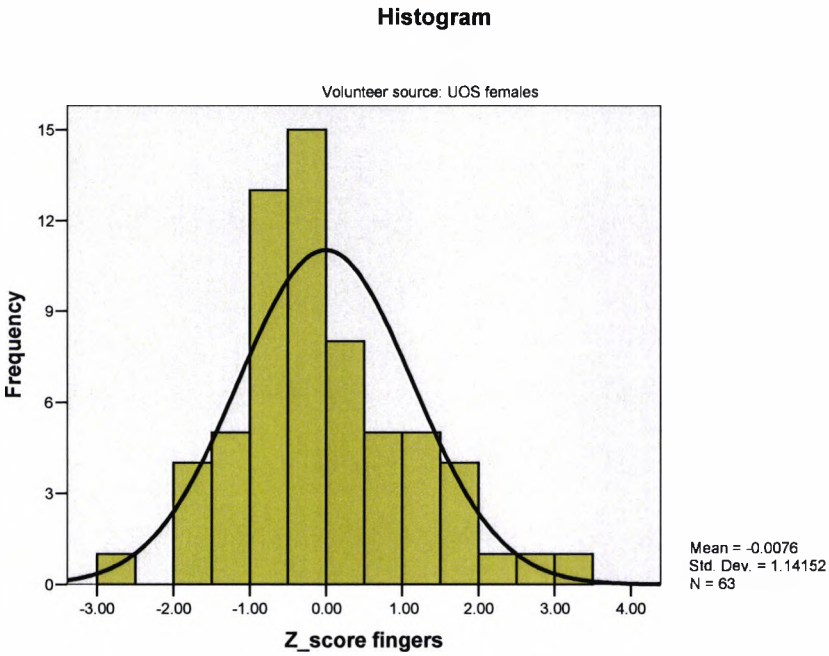


Figure 66 Phalangeal QUS Z-score (UOS females)

6.3.5.12 Phalangeal QUS, DWC Females

The histogram is shown for QUS phalanges.

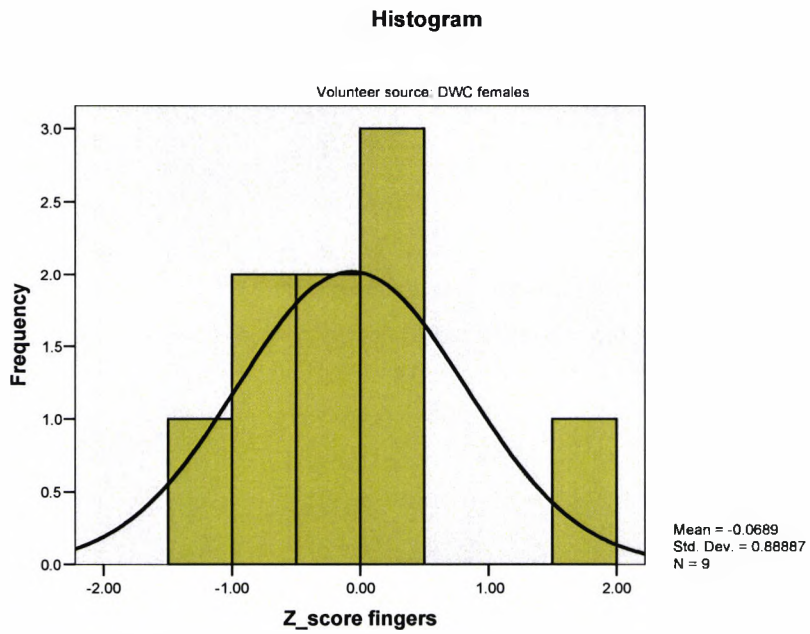


Figure 67 Phalangeal QUS Z-score (DWC females)

6.3.5.13 Phalangeal QUS, all Females

The histogram is shown for QUS phalanges.

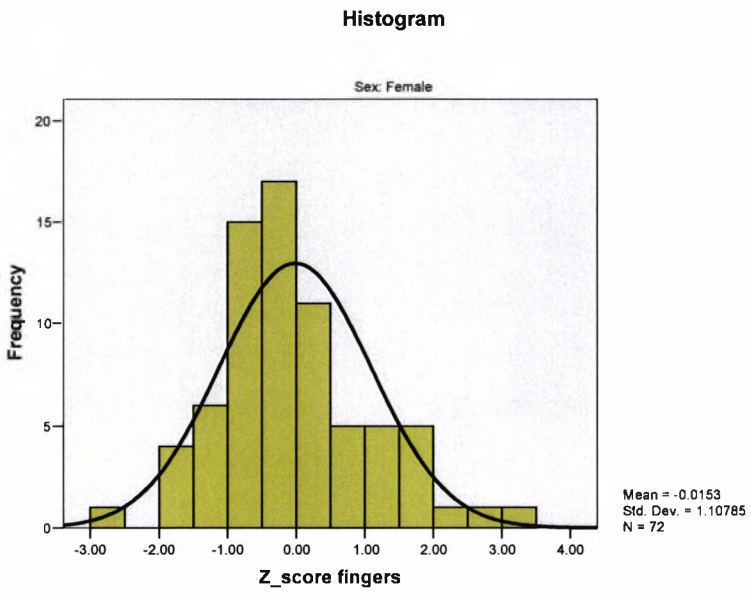


Figure 68 Phalangeal QUS Z-score (all females)

6.3.5.14 Prevalence of Osteopaenia Based on Caucasian Reference, All

The following bar graph shows the percentage of students from each group with low or normal bone density measured by QUS phalanges Z-score.

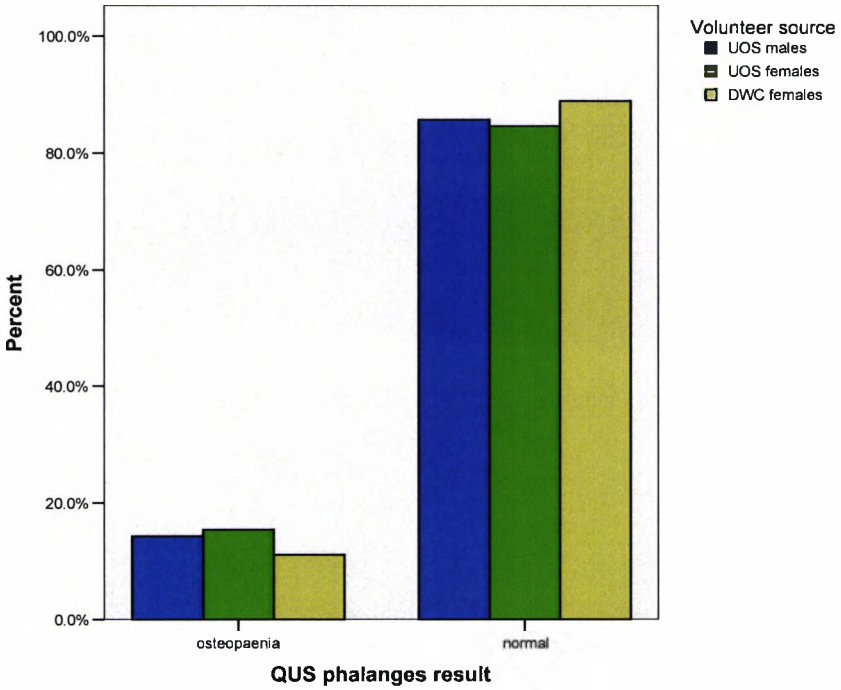


Figure 69 Percentage of osteopaenic students by group, QUS Z-score fingers

6.3.5.15 DXA Total Hip, Males

The data are shown for DXA total hip and when t-tested to the Caucasian mean of 1.037 g/cm^2 they were found to be the same (p = 0.971).

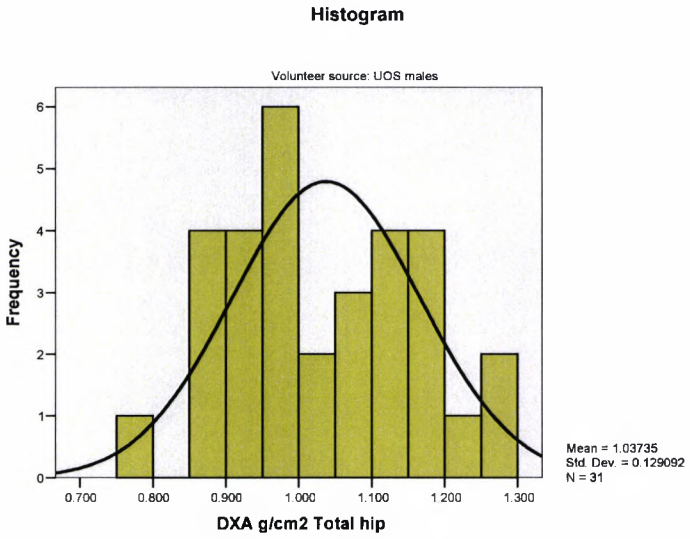


Figure 70 DXA total hip g/cm^2 (UOS males)

6.3.5.16 DXA Total Hip, Females

The data are shown for DXA total hip and when t-tested to the Caucasian mean of 0.943 g/cm^2 were found to be less by 0.113g/cm2 (p = 0.0001) or 12%.

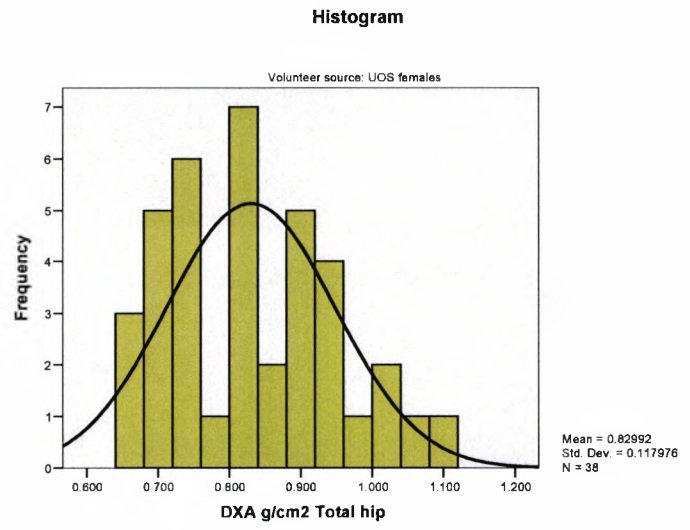


Figure 71 DXA total hip g/cm^2 (UOS females)

6.3.5.17 Representativeness of the DXA Groups to the QUS Heel Groups

The above analyses were done without examining the DXA group characteristics in comparison to the total QUS heel group characteristics. This is addressed now. Only a limited number of the QUS heel group had DXA scans for a variety of reasons even though they were offered to all UOS students. It is possible that the students who managed to attend for DXA may differ from the QUS group and therefore not represent them accurately. Therefore the groups were compared in the following way.

Descriptive characteristics were produced for the two DXA groups. Distribution of the data was checked with the K-S test for normality. The dependant variable of QUS left heel and DXA hip were found to be normal, and also BMI. The mean values of all characteristics were very similar to those for the total QUS groups. The males QUS value was slightly lower in the DXA group but not significantly. For the females, all characteristics were similar except for the QUS heel value which was significantly lower in the DXA group than the total QUS group. This probably occurred because females with lower QUS results were more likely to attend for DXA thus biasing the group to low bone strength students.

6.3.5.18 Prevalence of Osteopaenia Based on Caucasian Reference, All

The following bar graph shows the percentage of students from each group with low or normal bone density measured by DXA.

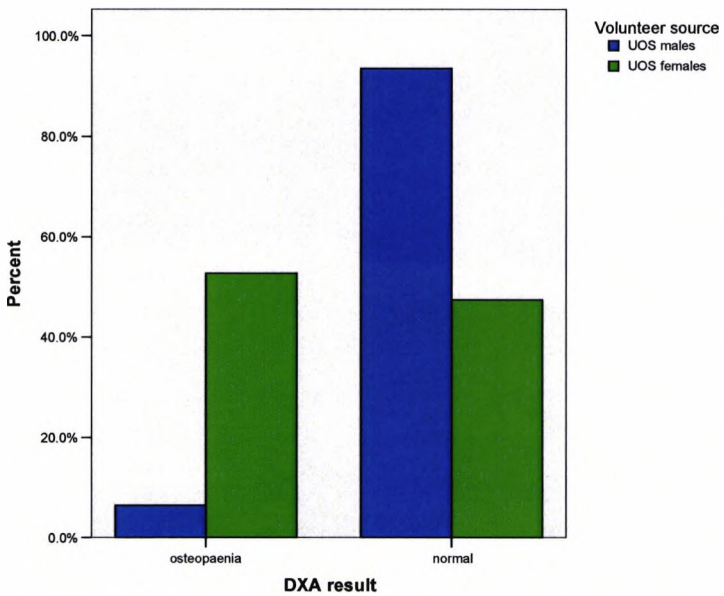


Figure 72 Percentage of osteopaenic students by group, DXA total hip g/cm^2

The number of males with osteopaenia is approximately 7% but the number of females about 54%.

6.3.5.19 Prevalence of Osteopaenia Based on UAE Reference, Females

The following bar graph shows the percentage of female students with low or normal bone density measured by DXA.

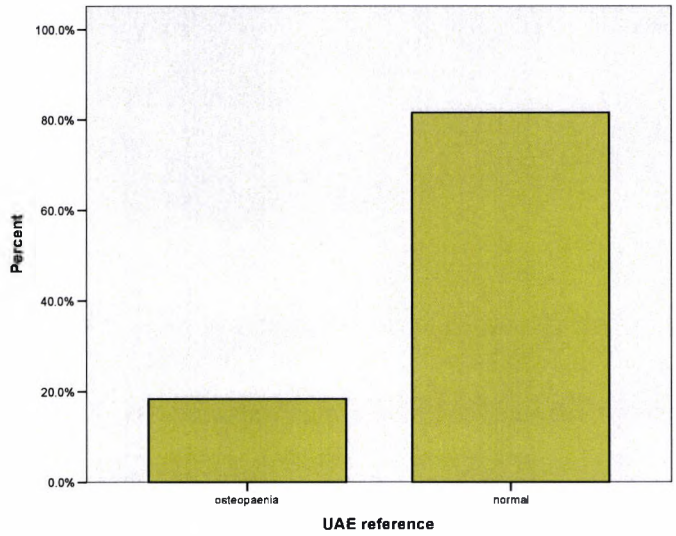


Figure 73 Percentage of osteopaenic females, DXA total hip to UAE mean

Using their own mean and standard deviation changes the number of females with osteopaenia to approximately 19%, reducing those affected by 75%.

6.3.5.20 Correlation between Bone Strength Measurements by T-scores and Z-scores

Heel T-scores for males were calculated from their own mean and SD on the Achilles ultrasonometer. No correlation was found between QUS Z-score phalanges and any other bone measurement T-score. Left heel T-score correlated with all DXA T-scores in the range of 0.550-0.599 ($p < 0.01$).

T and Z scores were chosen for this comparison because they are in the same units, SD, and only Z-score was usable for phalanges because other phalangeal values do not take into account the difference in ages of the students.

When only T-scores were compared between bone strength techniques this reduces the number of phalangeal results to those students who were at or above the young adult (PBM) age range available on the equipment. In both the DXA and QUS calcaneal correlations to QUS phalanges, the correlation is weak, not statistically significant and in the negative direction.

The gold standard currently for bone strength measurement is DXA. It was not possible to perform as many DXA scans as QUS calcaneum. Of the four measures of QUS SI for the calcaneum, correlations with DXA were explored for choosing the one which best correlates to DXA for subsequent risk factor analysis. For males and females, the best correlation to the DXA results was the QUS left heel and the DXA trochanter result best correlated to all QUS readings. The correlation for DXA total hip to QUS was good at 0.583 for the males and 0.473 for females ($p < 0.01$).

6.3.5.21 QUS Calcaneum, QUS Phalanges and DXA, Males compared to Females

The dependent variables of bone strength were inspected between males and females using t-tests.

Variables	*Males*	*Females all*	*Difference*	*p Value*
Height (cm)	175.4 ± 7.1	160.5 ± 6.1	14.9	0.001
Weight (kg)	76.0 ± 14	58.7 ± 12	17.3	0.001
BMI (kg/m^2)	24.6 ± 4	22.7 ± 4	1.9	0.001
SI lowest calcaneus	96.9 ± 15.3	91.5 ± 12.0	5.4	0.001
SI right calcaneus	100.9 ± 18.0	95.2 ± 14.1	5.7	0.004
SI left calcaneus	100.3 ± 16.0	94.3 ± 13.2	6.0	0.001
SI average calcaneus	100.7 ± 16.3	94.8 ± 12.9	6.0	0.001
total hip (g/cm^2)	1.037 ± 0.129	0.830 ± 0.118	0.207	0.001
neck of femur (g/cm^2)	0.902 ± 0.101	0.727 ± 0.113	0.175	0.001
trochanter (g/cm^2)	0.780 ± 0.106	0.622 ± 0.110	0.157	0.001
intertrochanter (g/cm^2)	1.233 ± 0.170	0.992 ± 0.135	0.241	0.001
neck of femur width (mm)	37.0 ± 0.23	31.0 ± 0.23	0.604	0.001
neck of femur narrow (mm)	36.7 ± 0.25	29.4 ± 0.22	0.731	0.001
neck of femur BMC (g)	4.99 ± 0.57	3.38 ± 0.62	1.62	0.001
vBMD (g/cm^3)	0.311 ± 0.043	0.299 ± 0.050	0.012	0.315
vBMD narrow neck (g/cm^3)	0.319 ± 0.049	0.335 ± 0.061	-0.016	0.234
AD-SOS phalanges (m/s)	2,111.1 ± 55.3	2,101.0 ± 52.5	10.09	0.316
UBPI phalanges	0.796 ± 0.089	0.748 ± 0.084	0.048	0.008
BTT (µs)	1.74 ± 0.19	1.47 ± 0.17	0.267	0.001

Table 37 T-tests bone strength, males to females

The standard results were almost all significantly different at the p = 0.01 level. Adult size variables and most bone strength variables were different between males and females as measured with heel QUS, DXA and finger QUS. Only SOS from QUS fingers was the same for males and females.

DXA only reports a two dimensional bone density. This does not take into account bone size. In fact, males and females are thought by some to have the same bone density (g/cm^3) and only differ on standard reports because their bone sizes are different and this is not

corrected for in two dimensions. In a report which demonstrated volume BMD in 20-29 year olds by Riggs (2004), females had higher vBMD than males.

In the above results, two volumetric BMD values are shown. The first uses the neck width from the area of the femoral neck box, the second one uses a narrower neck value as measured from the image using the DXA computer which is more accurately a representation of the neck. In both cases the difference between males and females disappears, the female neck BMD was 19% lower than the males but the female vBMD neck is statistically the same.

However, lifestyle risk factors are all also different (except for calcium intake). The females may have lower QUS just because they rarely exercise at all. Bone strength was different for males and females as measured with hip DXA as expected according to manufacturers reference data contained in the machine. Bone strength was different for males and females as measured with phalanges QUS for UBPI and BTT but the same for Ad-SOS. Fingers are less affected by lack of exercise which may account for the similarity between males and females for speed of sound measurements.

6.3.6 Risk Factors

6.3.6.1 Reliability and Validity

When the analysis was done, in this section, five groups were considered for student risk factor exposure. The groups were: 1/ UOS males, 2/ UOS females, 3/ DWC females, 4/ all females and 5/ all students. Correlations were produced between different measures of physical activity. Note: IPAQ includes all activity including walking but sports do not include walking as a past-time therefore the correlation is expected to be stronger where more sports are done. Good correlation was shown between all measures of sport and the IPAQ score, approximately 0.500 ($p < 0.01$).

Correlation between the number of milk drinks per week and calcium intake was on average 0.350 ($p < 0.01$) for all groups. More of the females calcium intake was from milk than in the male group. Correlation between the number of caffeine and carbonated drinks was around 0.475 ($p < 0.01$).

6.3.6.2 Exposure to Risk

In order to compare how much each group is exposed to risk factors for low bone strength the following clustered bar charts show each risk factor and the percentage of students in each category.

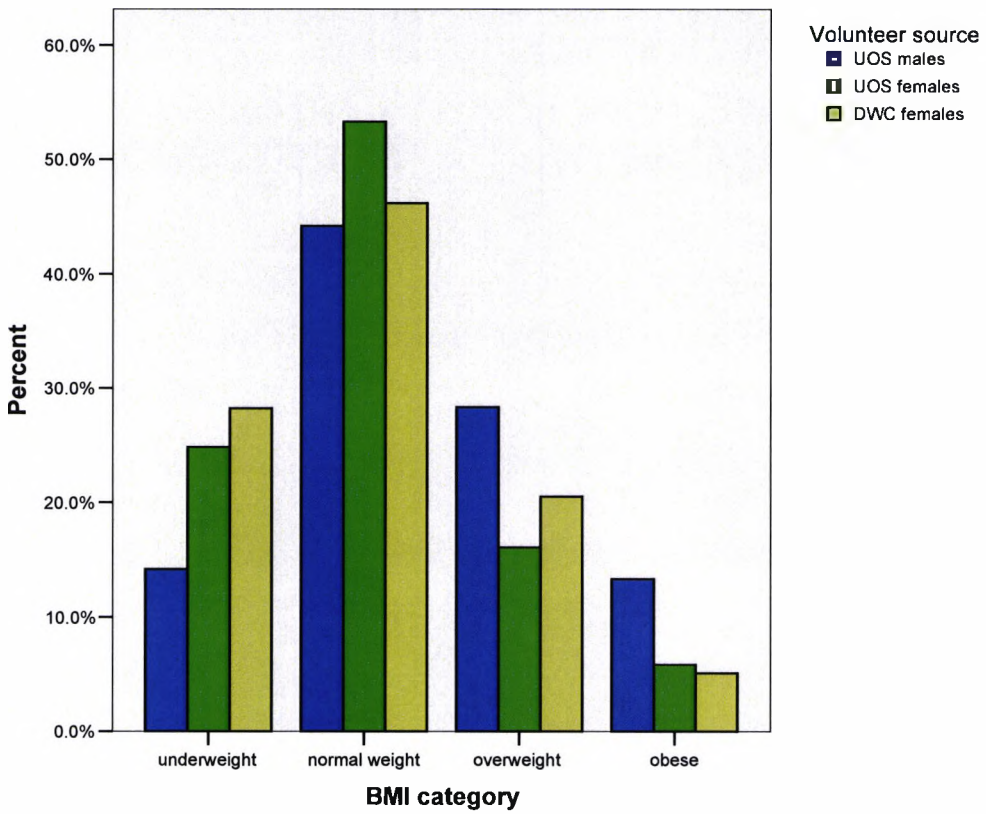


Figure 74 Percentage of students by BMI category per group

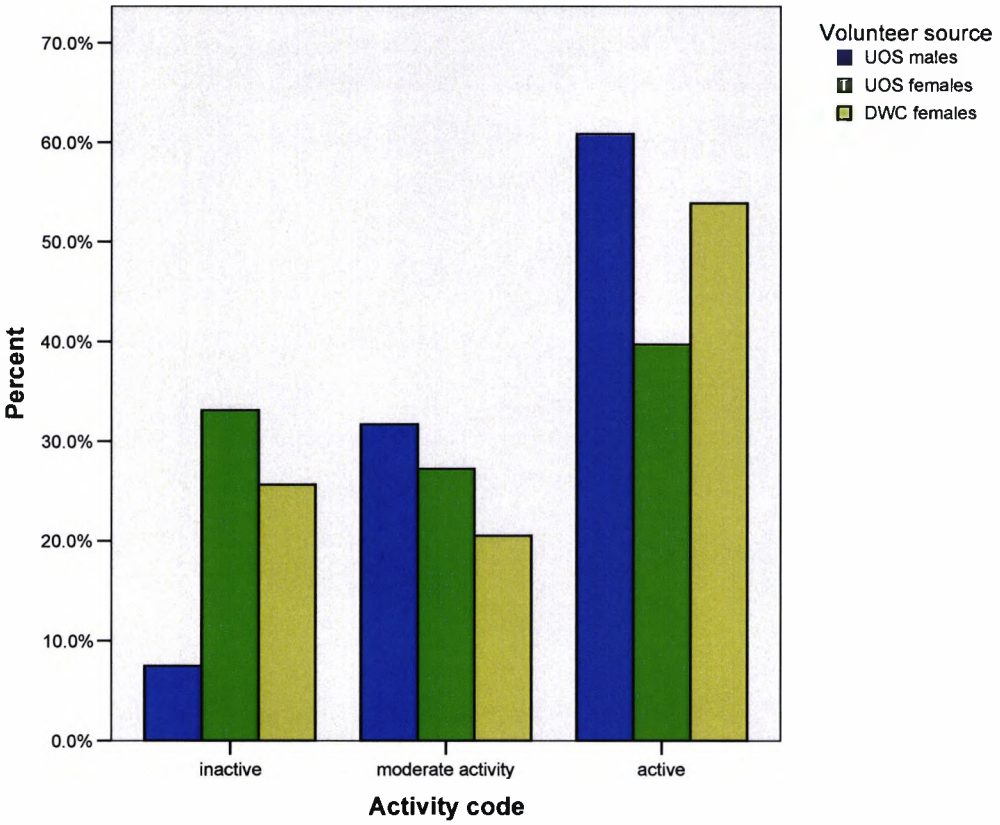


Figure 75 Percentage of students by activity category

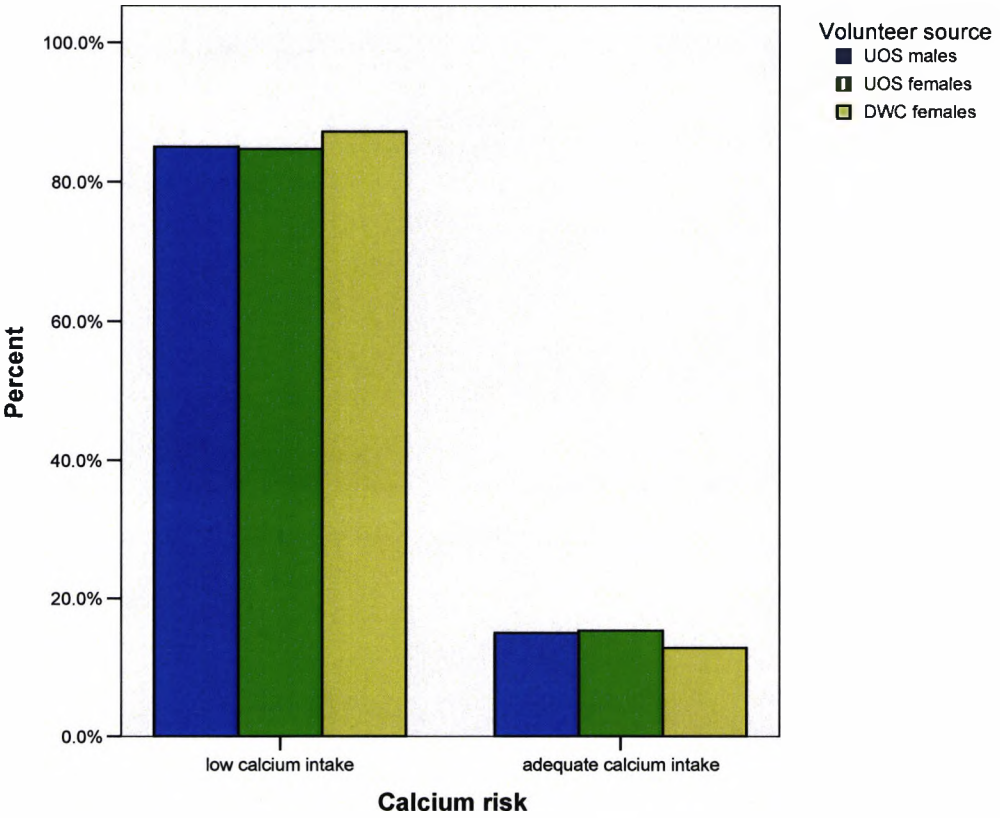


Figure 76 Percentage of students by calcium category

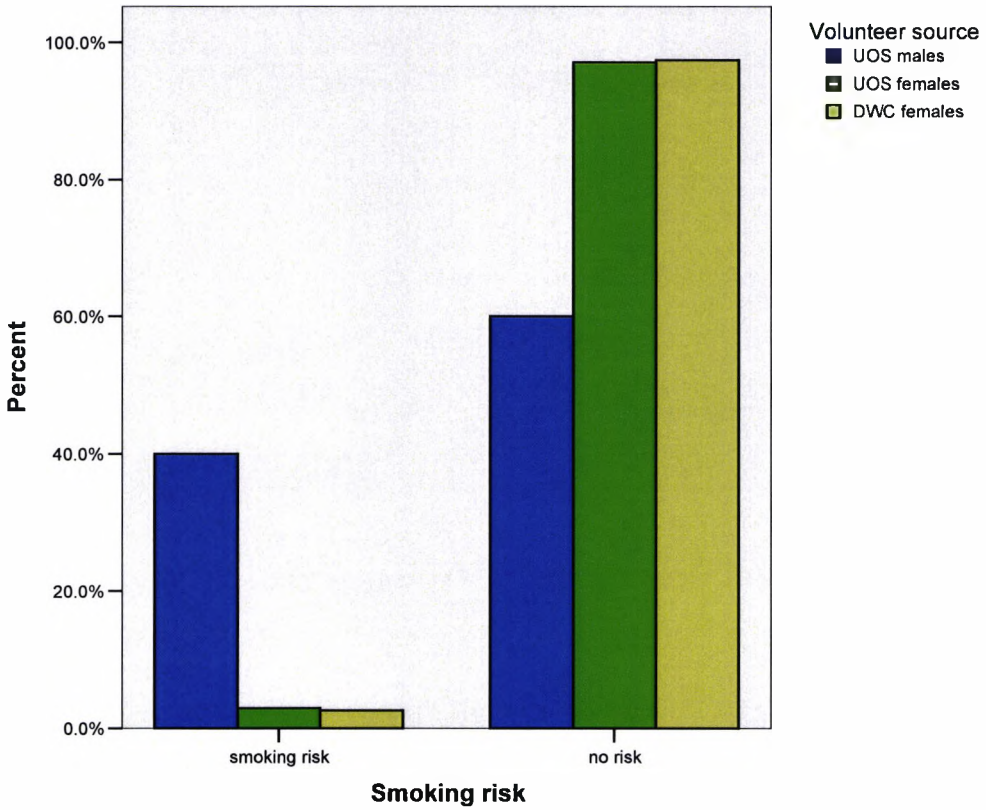


Figure 77 Percentage of students by smoking category

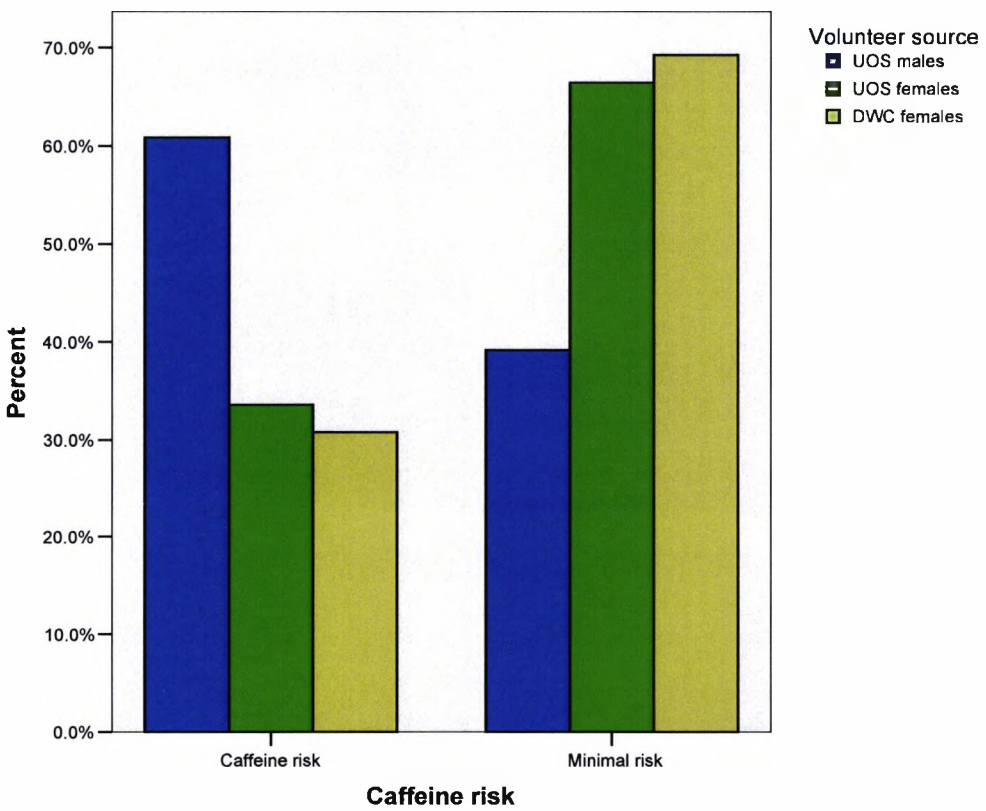


Figure 78 Percentage of students by caffeine category

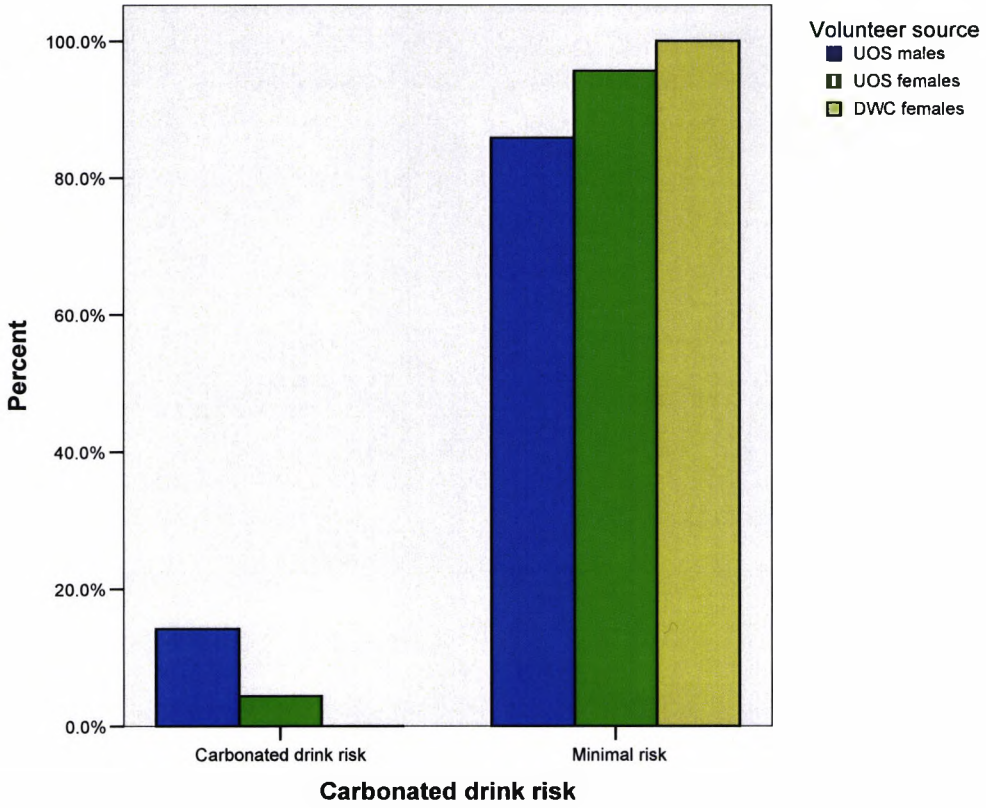


Figure 79 Percentage of students by carbonated drink category

In the case of menarche age, only 3 females started menstruating at 17 and none above that age. Therefore this risk bar chart is not shown as no students are considered at risk.

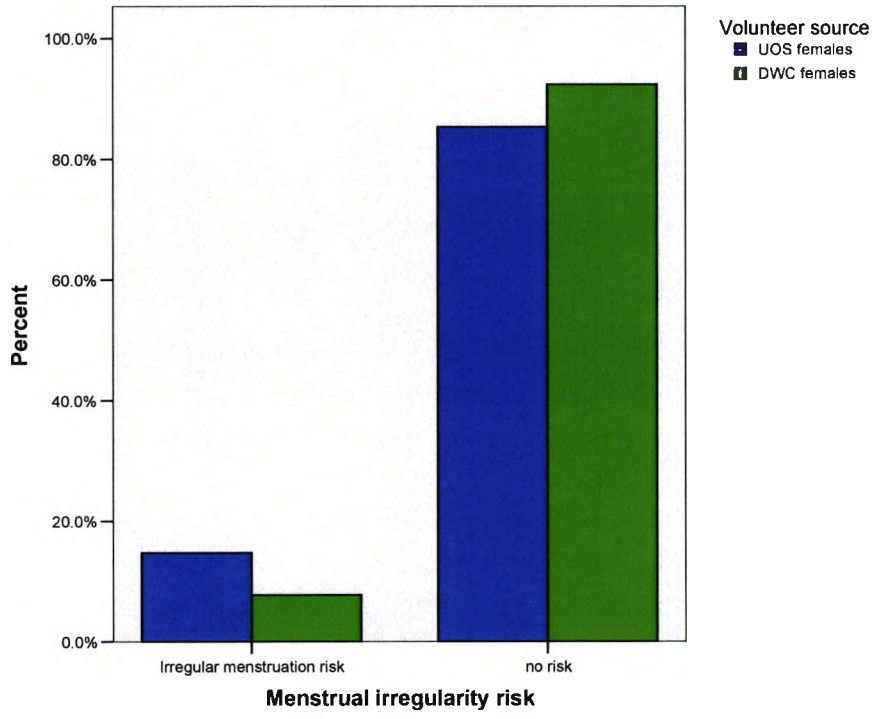


Figure 80 Percentage of females by menstruation category

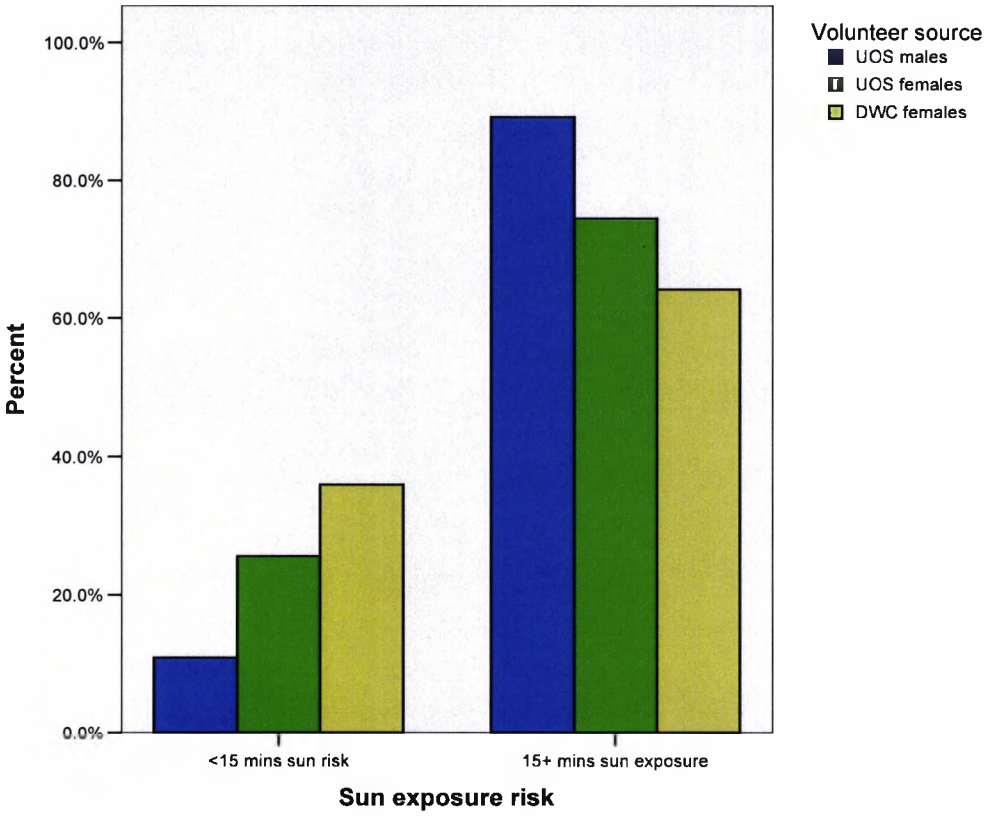


Figure 81 Percentage of students by sunlight category

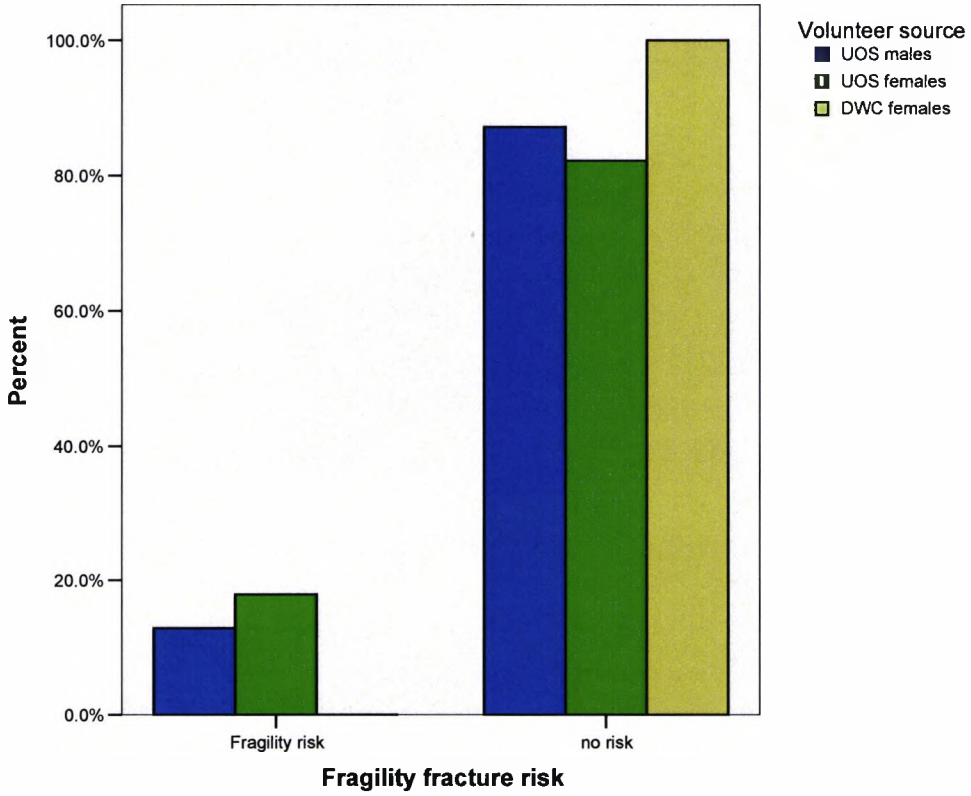


Figure 82 Percentage of students by fracture category

6.3.6.3 Comparison of Risks, Males to Females

The student exposure to risk factors could have been expected to be the same for males and females in most populations but in this case they are different. Comparison was made using the Mann-Whitney test. Results showed males and females differed in their risk factors significantly ($p < 0.001$) for all risks except for calcium intake ($p = 0.071$) and milk drinks ($p = 0.390$).

6.3.6.4 Odds Ratios

The variable categories which present a low bone density risk can be seen in the following table.

No.	Variable	Risk factor	Variable category
1	BMI	Underweight	< 20 BMI
2	Total sports	Low sports	< 4 units per week
2	Activity code	Low exercise level	Inactive
3	Calcium intake	Low	< 1200 mg calcium/day
4	Smoking	Smoker	Smoker
5	Caffeine	Cafffeine risk	3+ cans/day (> 714mg/week)
6	Carbonated drink	Carbonated drink risk	3+ cans/day
7	Menarche age	Late	> 17 years
7	Menstruation	Irregular	Absent 1 month +
8	Sun exposure	Inadequate	< 15 minutes of sun per day
9	Fracture	Fragility fracture	Minimal force fracture

Table 38 Risk Categories

The odds ratio shows the risk of having the first over the second outcome e.g. low/normal QUS calcaneum and can be calculated in the presence of a risk factor e.g. smoking or inadequate sun exposure. This odds ratios is only significant if the confidence interval does not include 1. Some of the risks assessed reach significance and some do not but in most cases there is increased risk of osteopaenia (a higher odds ratio) in the presence of the risk factor. If the odds ratio is more than 1 then there are more cases of osteopaenia than normal bone strength in the group who have the risk.

For these analyses, the group of all students was used on the basis that the risk would affect males and females in the same way and using all the students makes the power of the tests

much higher as there are larger numbers involved. The tests were then also run on each of the groups 1/ UOS males, 2/ UOS females, 3/ DWC females and 4/ all females. The results show that the risk factors studied do cause an increased risk of low bone density in many cases and are displayed below.

6.3.6.4.1 All Students:

QUS calcaneum result (low QUS / normal QUS)	N of Valid Cases	Odds Ratio	95% Confidence Interval	
Risk Factor			Lower	Upper
Low BMI	265	1.595	0.980	2.597
Low sports level	265	1.396	1.115	1.749
Low sun exposure	265	1.523	0.955	2.431
Fragility fracture	64	3.413	0.900	12.941

All students

Table 39 Odds Ratios QUS heel, all students

DXA result (low QUS / normal QUS)	N of Valid Cases	Odds Ratio	95% Confidence Interval	
Risk Factor			Lower	Upper
Low BMI	69	3.052	1.341	6.947
Low sports level	69	1.513	1.056	2.169
Low activity	69	2.747	1.176	6.414
Low milk	69	1.282	0.957	1.716
Low calcium	69	1.246	1.038	1.496
Low sun exposure	69	3.205	1.302	7.885
Fragility fracture	19	4.125	0.520	32.750

All students

Table 40 Odds Ratios DXA hip, all students

QUS phalanges result (low QUS / normal QUS)	N of Valid Cases	Odds Ratio	95% Confidence Interval	
Risk Factor			Lower	Upper
Smoker	109	2.422	0.986	5.947

All students

Table 41 Odds Ratios QUS fingers, all students

6.3.6.4.2 UOS Males:

QUS calcaneum result (low QUS / normal QUS)	N of Valid Cases	Odds Ratio	95% Confidence Interval	
Risk Factor			Lower	Upper
Low sports level	112	1.800	1.014	3.195
Fragility fracture	36	4.545	0.459	45.035

UOS Males

Table 42 Odds Ratios QUS heel, males

DXA result (low QUS / normal QUS)	N of Valid Cases	Odds Ratio	95% Confidence Interval	
Risk Factor			Lower	Upper
Low BMI	31	3.625	0.691	19.025
Low calcium	31	1.318	1.074	1.619
High caffeine	31	1.933	1.360	2.748
Low sun exposure	31	3.625	0.691	19.025

UOS Males

Table 43 Odds Ratios DXA hip, males

QUS phalanges result (low QUS / normal QUS)	N of Valid Cases	Odds Ratio	95% Confidence Interval	
Risk Factor			Lower	Upper
Low sports level	35	3.000	0.733	12.273
Low milk	35	1.333	0.787	2.258
Smoker	35	1.500	0.648	3.472
High carbonated drink	35	3.000	0.733	12.273

UOS Males

Table 44 Odds Ratios QUS fingers, males

6.3.6.4.3 UOS Females:

QUS calcaneum result (low QUS / normal QUS)	N of Valid Cases	Odds Ratio	95% Confidence Interval	
Risk Factor			Lower	Upper
Low BMI	120	2.466	1.346	4.518
Low sports level	120	1.136	0.913	1.412
High caffeine	120	1.381	0.841	2.267
High carbonated drink	120	2.158	0.456	10.201
Irregular menstruation	120	2.158	0.932	4.999
Low sun exposure	120	1.678	0.937	3.007
Fragility fracture	24	2.500	0.511	12.222

UOS females

Table 45 Odds Ratios QUS heel, UOS females

DXA result (low QUS / normal QUS)	N of Valid Cases	Odds Ratio	95% Confidence Interval	
Risk Factor			Lower	Upper
Low BMI	38	2.700	0.863	8.451
Low sports level	38	1.200	0.810	1.778
Low activity	38	1.620	0.666	3.939
Low milk	38	1.530	0.973	2.405
Low calcium	38	1.221	0.936	1.595
Irregular menstruation	38	3.600	0.442	29.303
Low sun exposure	38	3.600	0.877	14.784

UOS females

Table 46 Odds Ratios DXA hip, UOS females

6.3.6.4.4 DWC Females:

QUS calcaneum result (low QUS / normal QUS)	N of Valid Cases	Odds Ratio	95% Confidence Interval	
Risk Factor			Lower	Upper
Low sports level	33	1.538	0.840	2.817
Low milk	33	1.259	0.736	2.154
Low sun exposure	33	1.319	0.517	3.047

DWC females

Table 47 Odds Ratios QUS heel, DWC females

QUS phalanges result (low QUS / normal QUS)	N of Valid Cases	Odds Ratio	95% Confidence Interval	
Risk Factor			Lower	Upper
Low calcium	9	1.143	0.880	1.485
High caffeine	9	4.000	1.205	13.283

DWC females

Table 48 Odds Ratios QUS fingers, DWC females

6.3.6.4.5 All Females:

QUS calcaneum result (low QUS / normal QUS)	N of Valid Cases	Odds Ratio	95% Confidence Interval	
Risk Factor			Lower	Upper
Low BMI	153	1.895	1.093	3.284
Low sports level	153	1.182	0.959	1.457
High caffeine	153	1.091	0.685	1.738
High carbonated drink	153	2.000	0.418	9.562
Irregular menstruation	153	1.636	0.725	3.694
Low sun exposure	153	1.600	0.988	2.592
Fragility fracture	28	2.700	0.538	13.556

All females

Table 49 Odds Ratios QUS heel, all females

QUS phalanges result (low QUS / normal QUS)	N of Valid Cases	Odds Ratio	95% Confidence Interval	
Risk Factor			Lower	Upper
Low milk	74	1.061	0.858	1.312
High caffeine	74	1.245	0.603	2.570

All females

Table 50 Odds Ratios QUS fingers, all females

6.3.6.5 Receiver Operator Curves

Receiver Operator Curves (ROC) can investigate the relationship between two categories of one variable, for example presence or absence of a risk factor. An assessment can be made of the change from no risk to risk according to the value of the dependant variable bone strength.

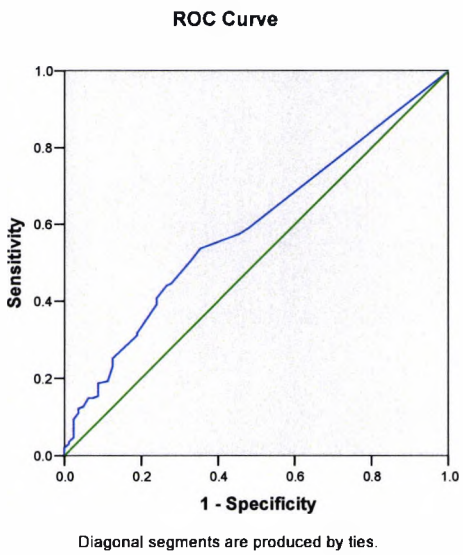
For this procedure to be done the dependant variable needs to have two categories or states also. These states will be normal or osteopaenic. Different devices have different values for these states which can be seen in the following table.

Measurement Device	Osteopaenia	Osteoporosis
Achilles	T-score ≤ -1.0	T-score below -2.5
DBM Sonic	Z-score ≤ -1.0	Z-score below -3.2
DXA	T-score ≤ -1.0	T-score below -2.5

Table 51 Categories of bone strength by measuring device

When running the test, the state of interest must be positive or have a value of 1.0. The result is an area under the curve. A result of 0.5 means that the item being tested makes no difference either way to the outcome of low bone density and guessing would give the same effect. The result is shown in graph format. The point on the plot closest to the top left hand corner of the graph is usually chosen as a cut-off for the test, balancing sensitivity on the y axis against specificity on the x axis. This cut-off point can then be used to find, from the table of values which accompany the curve, the value of the item being tested which indicates the positive state selected. Only the ROCs which reached statistical significance, and had a value above 0.5 are shown.

6.3.6.5.1 QUS Calcaneum, All Students



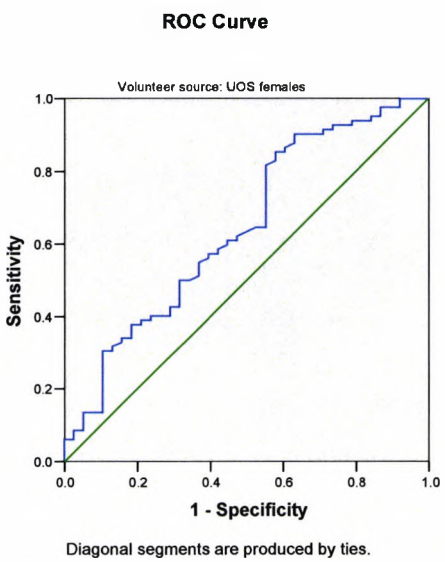
Area	Std. Error	p value	Confidence Interval	
			Lower Bound	Upper Bound
.591	.037	.020	.518	.663

Test Result Variable(s): Total units sport per week

Figure 83 ROC total units sport & QUS heel, all students

The positive actual state is normal heel QUS. The cut point is 3 units of sport.

6.3.6.5.2 QUS Calcaneum, UOS Females



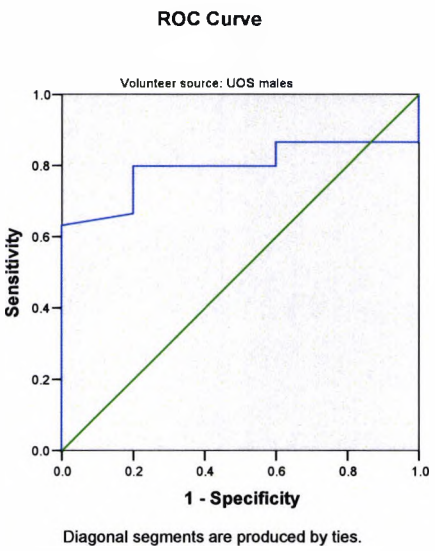
Area	Std. Error	p value	Confidence Interval	
			Lower Bound	Upper Bound
.643	.055	.012	.534	.752

Test Result Variable(s): Body Mass Index (BMI) kg/m2

Figure 84 ROC BMI & QUS heel, UOS females

The positive actual state is normal heel QUS. The cut point for equal sensitivity to specificity is 20 BMI.

6.3.6.5.3 QUS Phalanges, UOS Males

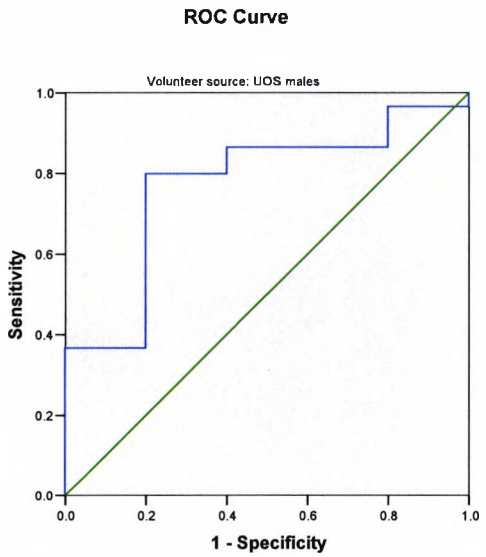


Area	Std. Error	p value	Confidence Interval	
			Lower Bound	Upper Bound
.797	.074	.036	.651	.943

Test Result Variable(s): Total sports new

Figure 85 ROC total sports new & QUS fingers, males

The positive actual state is normal fingers QUS. The cut point for equal sensitivity to specificity is 22 units of sports new.



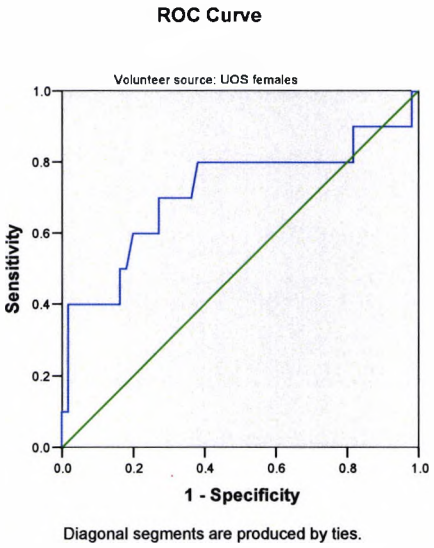
Area	Std. Error	p value	Confidence Interval	
			Lower Bound	Upper Bound
.773	.108	.053	.561	.985

Test Result Variable(s): IPAQ score

Figure 86 ROC IPAQ & QUS fingers, males

The positive actual state is normal fingers QUS. The cut point for equal sensitivity to specificity is 1240 IPAQ score.

6.3.6.5.4 QUS Phalanges, UOS Females

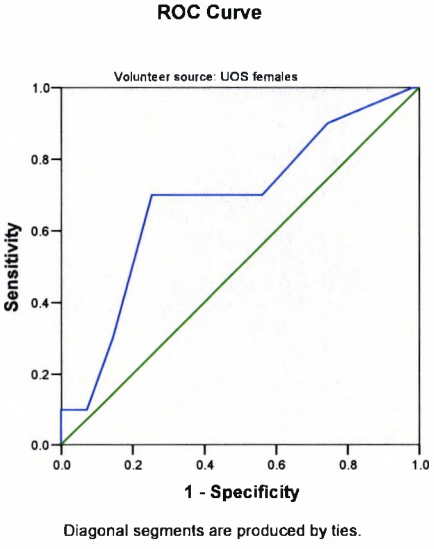


Area	Std. Error	p value)	Confidence Interval	
			Lower Bound	Upper Bound
.715	.108	.032	.503	.926

Test Result Variable(s): Body Mass Index (BMI) kg/m2

Figure 87 ROC BMI & QUS fingers, UOS females

The positive actual state is low finger QUS. The cut point for equal sensitivity to specificity is 19 BMI. This result is opposite to the others for BMI because as BMI goes up bones become osteopaenic.



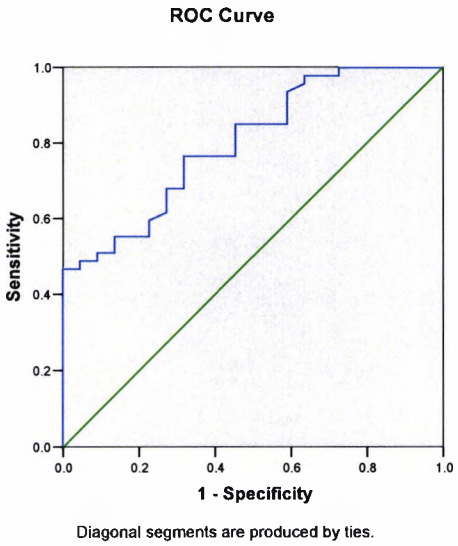
Area	Std. Error	p value	Confidence Interval	
			Lower Bound	Upper Bound
.681	.096	.070	.493	.869

Test Result Variable(s): Menarche age

Figure 88 ROC menarche age & QUS fingers, UOS females

The positive actual state is normal finger QUS. The cut point for equal sensitivity to specificity is age 12.

6.3.6.5.5 DXA Hip, All Students

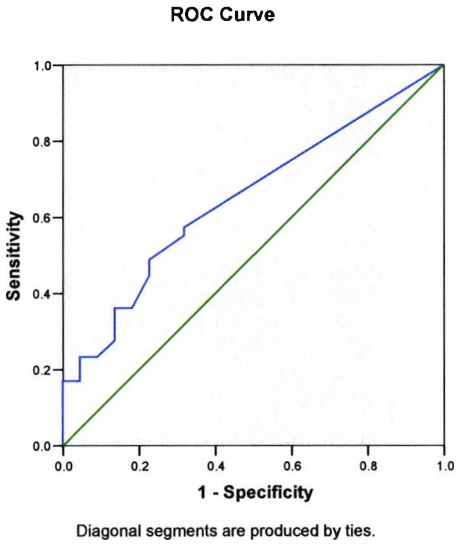


Area	Std. Error	p value	Confidence Interval	
			Lower Bound	Upper Bound
.801	.053	.000	.696	.906

Test Result Variable(s): Body Mass Index (BMI) kg/m2

Figure 89 ROC BMI & DXA hip, all students

The positive actual state is normal DXA. The cut point for equal sensitivity to specificity is 21.5 BMI.

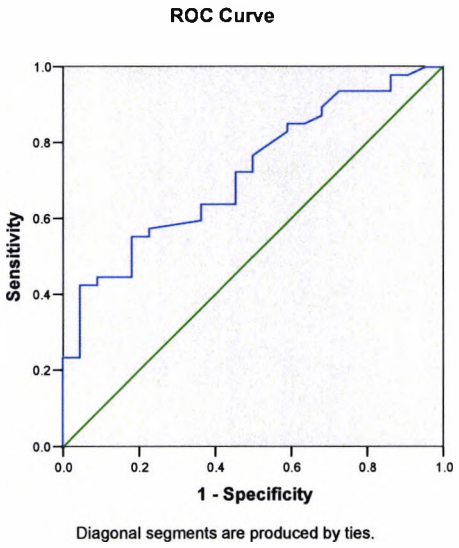


Area	Std. Error	p value)	Confidence Interval	
			Lower Bound	Upper Bound
.649	.068	.047	.516	.782

Test Result Variable(s): Total units sport per week

Figure 90 ROC total units of sport & DXA hip, all students

The positive actual state is normal DXA. The cut point for equal sensitivity to specificity is 0.5 units sport.

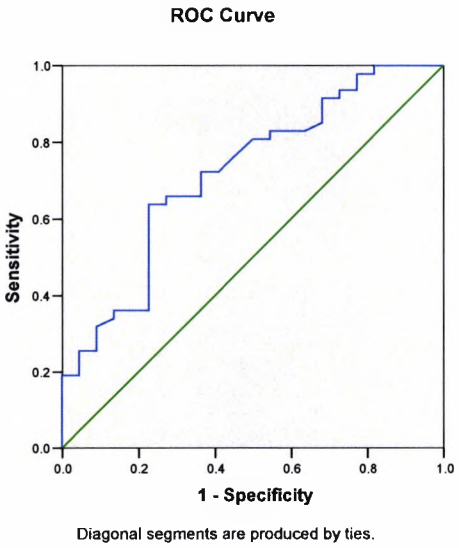


Area	Std. Error	p value	Confidence Interval	
			Lower Bound	Upper Bound
.721	.062	.003	.599	.843

Test Result Variable(s): IPAQ score

Figure 91 ROC IPAQ & DXA hip, all students

The positive actual state is normal DXA. The cut point for equal sensitivity to specificity is 820 IPAQ units.

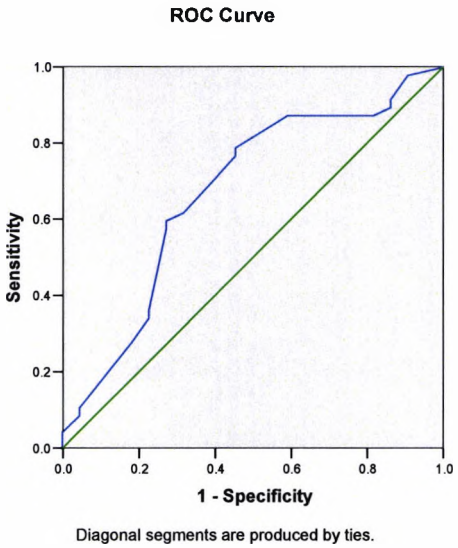


Area	Std. Error	p value	Confidence Interval	
			Lower Bound	Upper Bound
.721	.066	.003	.591	.850

Test Result Variable(s): Daily calcium intake (mg)

Figure 92 ROC Calcium & DXA hip, all students

The positive actual state is normal DXA. The cut point for equal sensitivity to specificity is 420 mg calcium per day.



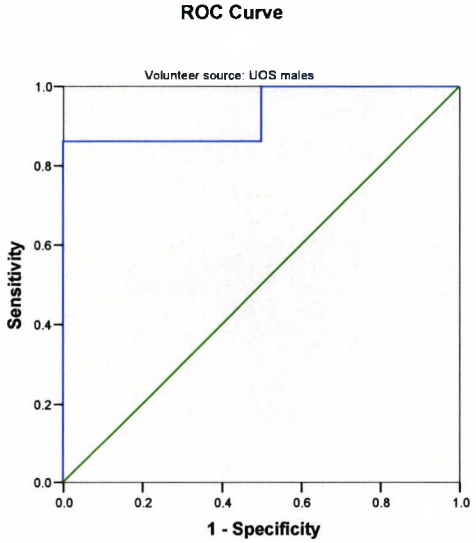
Area	Std. Error	p value	Confidence Interval	
			Lower Bound	Upper Bound
.671	.073	.023	.528	.813

Test Result Variable(s): Sun exposure per day (mins)

Figure 93 ROC sun exposure & DXA hip, all students

The positive actual state is normal DXA. The cut point for equal sensitivity to specificity is 15 minutes per day.

6.3.6.5.6 DXA Hip, UOS Males



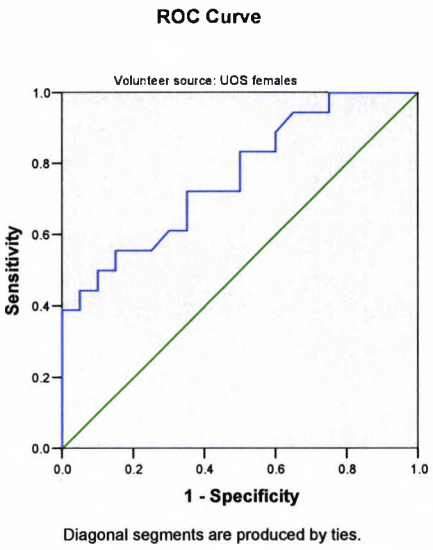
Area	Std. Error	p value	Confidence Interval	
			Lower Bound	Upper Bound
.931	.063	.044	.808	1.054

Test Result Variable(s): Body Mass Index (BMI) kg/m2

Figure 94 ROC BMI & DXA hip, males

The positive actual state is normal DXA. The cut point for equal sensitivity to specificity is BMI 21.

6.3.6.5.7 DXA Hip, UOS Females

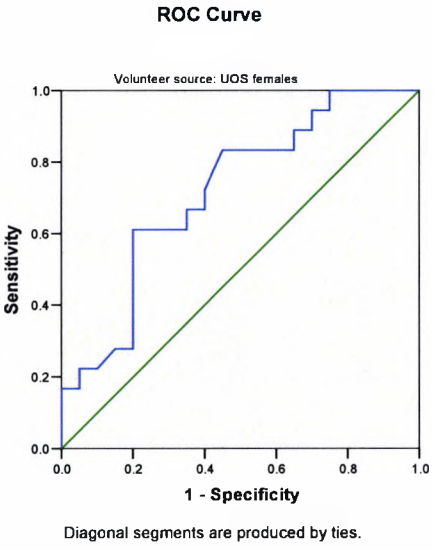


Area	Std. Error	p value	Confidence Interval	
			Lower Bound	Upper Bound
.764	.077	.005	.613	.914

Test Result Variable(s): Body Mass Index (BMI) kg/m2

Figure 95 ROC BMI & DXA hip, UOS females

The positive actual state is normal DXA. The cut point for equal sensitivity to specificity is BMI 21.

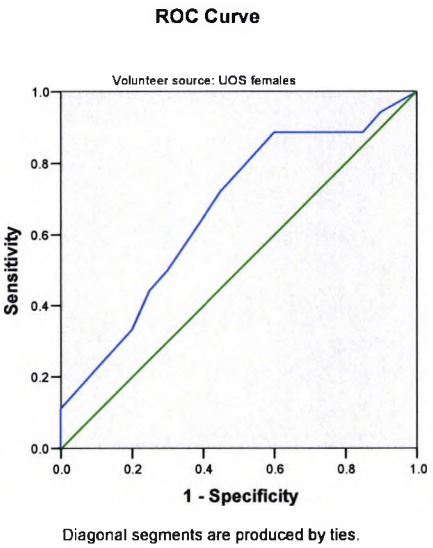


Area	Std. Error	p value	Confidence Interval	
			Lower Bound	Upper Bound
.718	.083	.022	.554	.882

Test Result Variable(s): Daily calcium intake (mg)

Figure 96 ROC calcium & DXA hip, UOS females

The positive actual state is normal DXA. The cut point for equal sensitivity to specificity is 380 mg calcium per day.



Area	Std. Error	p value	Confidence Interval	
			Lower Bound	Upper Bound
.665	.089	.082	.491	.840

Test Result Variable(s): Sun exposure per day (mins)

Figure 97 ROC sun exposure & DXA hip, UOS females

The positive actual state is normal DXA. The cut point for equal sensitivity to specificity is 23 minutes of sun per day.

6.3.6.6 Regression

Correlations were run on all variables before performing regression. The tables are not shown as they are too large but can be found in the appendices R, S and T. Regression is used to predict the presence or absence of an outcome, low bone strength, based on a set of predictor variables which in this study are the 9 risk factors. The dependent variable of bone strength is a scale variable therefore linear regression is used. The independent variables can be scale or dichotomous. Variables which are chosen to be included in the model should have already shown a correlation to the dependent variable and must not have collinearity.

Correlations were tested and several variables found which correlated with QUS for the males however collinearity was found between them, prohibiting all of them being used in the regression model at the same time.

6.3.6.6.1 Males, QUS:

The male model for QUS SI left heel approached significance for total units sports per week predicting the outcome ($p = 0.090$).

6.3.6.6.2 Females, QUS:

The female model for QUS SI left heel approached significance for total units sports per week predicting the outcome ($p = 0.051$) and BMI predicted the outcome with significance ($p = 0.003$).

6.3.6.6.3 Males, DXA Total Hip:

The male model for DXA total hip approached significance for number of previous fractures ($p = 0.086$) and daily calcium intake ($p = 0.058$) predicting the outcome, whilst BMI predicted the outcome with significance ($p = 0.009$).

6.3.6.6.4 Females, DXA Total Hip:

In the female model for DXA total hip, BMI ($p = 0.001$) and number of milk drinks per week ($p = 0.050$) predicted the outcome with significance.

7. DISCUSSION

7.1 Introduction

The study of bone strength for the purpose of understanding and preventing osteoporosis has been gathering momentum worldwide over the last few years. When this project was conceived there were no published studies on bone strength in the UAE. To-date there are now three papers based on UAE subjects, all by the same group at Emirates University in Al Ain. However, these papers all addressed only national females. Since nationals account for only 20% of the population this left a large group of non-national Arabs about whom nothing was known. Bone strength in males in the UAE had never been addressed until now, even though males also suffer serious consequences from osteoporosis.

The data gathered on UAE females indicated that they have lower bone strength than their Caucasian counterparts. The cause for this was unknown but was suggested to be a combination of vitamin D deficiency and genetic factors, i.e. a naturally lower bone strength in the same way that Caucasians have lower bone strength than Africans.

Secondary level education is extremely prevalent in the UAE partly due to the government's commitment to education and partly due to the affluence of the expatriates employed here. The University of Sharjah opened in 1997 and quickly grew into a large, successful establishment attracting students from a diverse range of countries, predominantly Arab. The researcher, having been a lecturer at this university for several years, felt that it would provide an ideal setting to base a research project which focused on the youth of the nation.

At this point it is worth repeating the aims of this research study as follows:

1. Address the gap in knowledge regarding the normal bone strength of Arabs, national and expatriate, males and females, in the UAE.

2. Describe mean bone strength values for UAE students and compare to known normal values for other ethnic groups.

3. Discover the prevalence of low bone strength.

4. Highlight cases of low bone strength to students.

5. Investigate dietary factors and exercise levels, in order to determine whether they fulfill recommended criteria for the prevention of osteoporosis.

6. Compare the prevalence of osteoporosis risk factors between males and females.

7. Investigate the use of a new technique for bone assessment.

8. Aid in the dissemination of information regarding awareness of osteoporosis and its risk factors.

9. Discover whether there would be a need for further intervention in modifiable lifestyle factors which could be implemented through the educational setting.

This chapter will demonstrate that all the aims and objectives of the project were achieved. The results will be discussed in detail in reference to the aims, objectives and hypotheses. The first part of this chapter will comment on the pilot study and the second part will discuss the full study.

7.2 Pilot Study

7.2.1 Sample

7.2.1.1 Size

The sample size was small for detailed statistical analysis, although preliminary measures were carried out that were a pro forma of later work. The full study would include a minimum of 84 in each group and if possible 96.

Students were very keen to join the pilot study. From the opening time onwards, for males and females, there was a queue for the bone density measurement. This did not seem to be only people interested in their health, but rather general curiosity. Nobody refused to consent. This

helped to make the study as unbiased as possible, considering it was a convenience method.

The principal researcher was able to collect all data personally aided by some English/Arabic translation either by other students or research assistants. The two samples of n=30 and n=35 were each dealt with in a day which indicated that increasing the number four fold would be feasible if data collection was for considerably longer.

7.2.1.2 Geographical Background

The nationality of the students was varied. All ethnicities had been included, which meant that the group consisted of Arab and African ethnic subjects although the African subjects were later removed from the data. Only a very small number (7% of the males and 31% of the females) were UAE nationals. However, the majority (82% of males, 83% of females) had lived most of their life in the UAE and more than half (56% of males, 69% of females) were born in this country, which indicates all students would have been exposed to a similar lifestyle in terms of available diet and UAE norms for exercise participation in schools and at home.

7.2.2 Arab Bone Strength

Arab bone strength, as estimated during the pilot study using QUS, was found to be statistically lower than the European reference range quoted by Hologic (Sahara manufacturers). This was in line with other studies of the Arab populations (Saadi 2003, Maalouf 2000). In Saudi Arabia Ardawi *et al* (2004) commented that, on their study of a large number of males and females, the prevalence of osteoporosis in older people (50-79 years) was up to 50% if the equipment manufacturer's reference range was used. Their random study included 1,980 healthy Saudis (915 males and 1,065 females) who had DXA of the spine and hip. The authors noted similar age related decreases in BMD as had been shown in other countries. The article stresses the author's belief that population specific reference values must be created to avoid over or under estimating osteoporosis. In another, earlier, study by Ghannam (1999) it was concluded that healthy Saudi females had significantly lower BMDs than US females. Studies showing bone density in this population are vital in order to allow the same focus on osteoporosis here as there is in the rest of the world. The economic implications of ignoring osteoporosis have been highlighted in the literature review.

The mean estimated BMD for the males was 0.574 ± 0.07 g/cm^2, 0.560 ± 0.07 g/cm^2 for the females. As defined by the WHO (although for DXA BMD in postmenopausal white women) osteopaenia would be more than 1 SD below the mean. The mean estimated QUS BMD for the Sahara machine is 0.58 g/cm^2 and 0.46 g/cm^2 is 1 SD below that from the European female reference range. As there was no other accepted scale to use at the time, these figures were used in terms of guidance. Using this reference, 2 males were classified as osteopaenic. This was surprising as it was expected that the females would be more at risk than males, however the study size was small. The two males in question both reported doing no exercise, drinking carbonated and caffeine drinks (one of them drank 3 or more caffeine drinks per day and the other 1 per day, one of them drank 2 carbonated drinks per day and the other 2 per week) and one of them was the only underweight male in the group.

The first hypothesis, that Arabic bone density is different, lower, than the reference value for European females, was tested with the pilot data. Pilot data showed that the average estimated BMD from QUS was 0.560 g/cm^2 for young adult females. The reference value for the Sahara QUS machine for European females is 0.580 g/cm^2. The null hypothesis is stated below:

H_0: $\mu = \mu_0 = 0.580$ g/cm^2

A one sample t-test was performed against the value 0.580 g/cm^2 to determine whether the hypothesis was to be accepted or rejected. The result showed that the UAE pilot mean BMD for females was significantly lower than the reference value for European females, which means that the null hypothesis can be rejected at the 95% confidence level; the BMD of Arab female students is statistically lower than European females. This was preliminary data only, on a small sample and it was hoped that increasing the sample size three or four-fold would increase the significance of this finding considerably.

The number of students in the pilot was small, but the data appeared to suggest links between risk factors and low BMD.

7.2.3 Risk Factors

The pilot study showed that in 2 risk factors the males were statistically different from the females; they drank more caffeine and carbonated drinks and therefore were at higher risk of

low BMD. Males drank an average of 5 more caffeine drinks per week than females and eight more carbonated drinks. The study also indicated that females perform little exercise, as was expected by the author. As the males differed from the females, one set of guidelines for improving lifestyle would not necessarily be appropriate for both groups, they should be tailored to target the prevalent risks found.

Males and females appeared to consume the same number of milk drinks and eat the same number of calcium containing foods. Number of days per week when exercise was done was also similar. However, it is acknowledged that the numbers in each group were small, causing the spread for each average to be large therefore making it difficult to see a difference where the confidence interval of means overlapped, for example that males perform more days of exercise per week.

The results exploring the influence of risk factors on mean QUS BMD for males showed that for almost all risk factors (except smoking and previous fracture) the mean BMD of the group at risk was lower than the mean of the group not considered to be at risk, indicating that these risk factors were indeed influencing BMD. However, again due to the small numbers involved in this sample, most of the traits seen were not significant with the exception of exercise.

In the female group, the only statistically significant correlation was between BMD and BMI, Pearsons rho = 0.398 ($p = 0.027$). No other links could be seen but the number of students exercising was low as was the number consuming caffeine or carbonated drinks, compared to the males.

7.2.3.1 Low BMI

BMI could not be assessed because only 1 male had a BMI value of less than 20. Not surprisingly, no correlation was seen for the males between BMD and BMI. The one male with low BMI was one of the 2 lowest BMD values in the study of males. In females, there was a correlation between BMD and BMI; having a low BMI predisposed the student to a low BMD. This result complied with the literature. When comparing means, the female results were rather different from the males. BMI gave a lower BMD mean for the underweight BMI category compared to the other group, but not significantly.

7.2.3.2 Nil or Minimal Physical Exercise

For males both exercise level and number of days of exercise per week showed some correlation. Exercise level showed a correlation of 0.343 ($p = 0.087$). Number of days of exercise per week correlated more strongly with a coefficient of 0.445 ($p = 0.023$).

When comparing estimated BMD in the presence or absence of risk, the group of males at risk who took exercise 3 days per week or less had a lower BMD ($p = 0.064$). The BMD of the "at risk" group was 10% lower than those more regularly exercising. Those males who performed nil or only minimal levels of exercise had a statistically significant ($p = 0.014$) lower BMD value than males who performed moderate levels of exercise. They had an average of 0.065 g/cm^2 lower BMD than those without this risk factor, or 11% less bone. The questions pertaining to physical exercise were not precise enough. Exercise needs to be quantified and also only certain types of exercise, high impact weight bearing, has positive effects on BMD whereas others such as walking or swimming do not. There were positive results indicating effects of exercise on increasing BMD.

The number of females performing exercise was very low. Only 4 females reported exercising more than 3 times per week and only 3 performed exercise at a moderate level.

7.2.3.3 Low Calcium Intake

The number of milk drinks per week correlated weakly, $\rho = 0.268$ for males and 0.174 for females, but without significance. Calcium intake was poorly measured although some studies have commented that just questioning how much milk is drunk is as valid as assessing all calcium containing foods as milk has the highest calcium concentration, other foods offering much less.

7.2.3.4 Smoker

Only males smoked and this is one of the important differences between males and females. No females reported being current or ex smokers as was expected based on cultural knowledge of the area. Only 8 males in this group smoked but more smokers were expected for the full study.

7.2.3.5 High Caffeine or Carbonated Drink Consumption

The correlations for caffeine and carbonated drinks to BMD were not significant but were in

the negative direction for males as was expected; females did not consume as much of these drinks. Interestingly, increased caffeine consumption and carbonated drink consumption both lowered BMD in the "at risk" analysis but again without statistical significance. Males but not females showed high levels of caffeine and of carbonated drink consumption. Carbonated drink consumption could not be assessed for females as they drank very few fizzy drinks.

7.2.3.6 Oestrogen Deficiency

The questions regarding start of menarche and menstrual regularity were imprecise. If age at menarche had been requested, a correlation could have been looked for between this and BMD.

7.2.3.7 Fragility Fracture

Incidence of fracture did not prove to be linked in any way for the males but for females with fractures the mean BMD was higher than those without. However, the question about incidence of a previous fracture did not ask how it occurred and therefore was not much use. The new instrument asked whether the amount of trauma was in keeping with the fact that a fracture occurred thus trying to distinguish fragility fracture from non fragility although in a young healthy group it is still not expected to have occurred often if at all.

7.2.4 Evaluation of Pilot

7.2.4.1 QUS

QUS, although not the best predictor of bone density, is valid for assessing bone strength and in combination with risk factor analysis is useful in highlighting at risk individuals for low bone mass. In the full study DXA was added although QUS remained the method of choice because it is completely safe and easy to perform.

7.2.4.2 Lifestyle Instrument

The lifestyle instrument, constructed by the author, performed reasonably well but needed to be redrafted to be more consistent as has been mentioned in the preceding comments.

7.2.4.3 Strengths and Weaknesses of Pilot

The strength of the pilot study was the fact that BMD was found to be significantly lower than the European reference figure. Also the highlighting of present risk factors, different for males

and females was of importance.

The weaknesses included the small sample size, inadequate information for risk factors and lack of DXA measured BMD to validate the QUS findings.

7.2.5 Action

The full study rectified the previously mentioned weaknesses. Data collection tools were modified and improved. The food frequency component for assessing calcium intake was taken from an original produced by the National Academy of Sciences and exercise was measured using the validated International Physical Activity Questionnaire.

Questions were added, for example about which major is being studied. This allowed an analysis of which groups of students attended in order to protect from accepting more health science students than other groups such as engineering or business. Health science students could be more aware of their health and be behaving in a more healthy way than other students, thus biasing the study.

The full study added DXA for some students and correlated QUS and DXA results. MRI was employed for a small number of students as a pilot for further bone strength analysis.

7.3 Full Study

7.3.1 Objectives

The first study objective of this research project was met by the collection of a large cross-sectional convenience sample of students from the University of Sharjah and the Dubai Womens College. Objectives 2, 3, 4 and 5 concerned using four methods of bone strength assessment to investigate the subjects, this task was accomplished and results have been presented. The 6th objective of the project was to look at correlations between the techniques. This is addressed in the section of the results entitled correlation between bone strength measurements.

The lifestyle tool succeeded in gathering information on lifestyle factors which are described in detail, fulfilling objective 7 and revealing much about the habits of the UAE student. Correlations between risk factors and bone strength, objective 8, are tackled in more than one way including looking at relative risks and receiver operator curves as well as correlations and finally regression. Objectives 9 and 10 were performed in the field, the students were advised of their results after their scans and requested to seek further medical advice in the case of low bone density.

Objective 11 remains to be completed, to disseminate statistically significant results, but will begin with the submission of this thesis. It is hoped that the information gained in this study will be beneficial to the UAE population as well as offering new directions of research for the future. Certainly much excitement and interest was generated in the student body concerning the possible risks to their bones from adopting an unhealthy lifestyle. If nothing else, hundreds of students are now more aware of the need to exercise and include adequate calcium in their diet than before the project started.

Finally, the primary hypothesis that Arab bone strength is lower than the Caucasian reference was proved to be correct for females, who have a 9% lower QUS heel mean value than Caucasian females and a 12% lower mean for DXA of the hip. Males, however, were found to have equal bone strength by DXA to Caucasian males. Secondly, bone strength risk factors are present and evidence of their effects are shown.

7.3.2 Sample

A total of 337 students were recruited overall. This number was reduced by 12% to 296 after participants who had exclusion criteria were identified. Not being able to remove these volunteers until after completion of their QUS scans was time wasting but avoided their embarrassment in front of their peers had they been denounced as ineligible. Students, being less emotionally mature than their seniors, are very sensitive to embarrassment and the opinions of their friends and peers. If any students had been disgruntled with their treatment they may have passed a negative opinion of the project to their friends and discouraged them from volunteering. A convenience sampling technique was used which meant allowing students to volunteer for the study. This proved to be very successful. The numbers recruited to the study were large for both males and females. That there was no problem recruiting volunteers speaks for the fact that the researchers managed to maintain a professional but friendly and encouraging atmosphere.

7.3.2.1 QUS Calcaneum

Heel QUS scans were the main focus of the project because they were simplest to do and available on site. These scans were completed in the first phase of the study on 265 students; 153 females and 112 males. Both heels were scanned therefore this was actually a total of 530 scans performed.

7.3.2.2 DXA Hip

69 DXA scans on 38 females and 31 males were performed in the second phase of the project. These proved more difficult to recruit for simply because of time constraints on the part of the students. Far more participants were willing to have the exam than those who actually attended. The fact that these scans were being undertaken in the second half of the semester had a huge impact on the availability of the students. Often they committed to an appointment which they then subsequently cancelled due to either pressure of work yet to be completed or because their professor had announced an extra quiz. The number of scans done did not reflect the amount of time devoted to them and this was a negative aspect of the project. The time needed to get to the scanning site and back was a total of 3 hours although the actual scan for one student took less than 1 minute. However, time spent traveling was fruitful as the researcher answered questions and generally promoted osteoporosis awareness.

7.3.2.3 QUS Phalanges

The third measurement technique of QUS phalanges was included when the company offered to lend the equipment after they heard about the impending start of the project. Unfortunately, the equipment was taken back for demonstration use by the supplier before the end of the QUS scanning time. This caused the number of QUS phalangeal scans to be considerably lower than the number of QUS heel scans. 125 phalangeal QUS scans were done on 81 females and 44 males. The equipment was not as easy to use. It took considerably more time to perform the QUS of four phalanges than it did to complete a heel scan. In the main this is because of having to remove the device from a finger, reapply gel and then replace on the next finger. Care needed to be taken and the procedure could not be rushed because the caliper holding the two transducers was very tight and could be uncomfortable if incorrectly placed.

7.3.2.4 Bias

The possibility of sample bias was considered at the outset as it occurs were volunteers are used for the sample. A random sampling technique would have been preferential. One type of bias could have occurred if the sample contained a larger proportion of health science students than others, but only if they differed from other students by being more health aware and thus healthier.

Bar graphs are presented in the results to show the number of students from each college. A good spread of students representing each college was obtained. This was achieved through careful marketing of the study and distribution of the data collection schedule prior to commencement of scanning. The research was performed on location in each of the concerned colleges. The researchers were on site at each place from the beginning to the end of each day thus allowing students to find them whenever their timetable allowed a break from classes.

In the male group there were more engineering students than any other college but not more than 38% of the total. In the females there were more health science students than any other college who represented 39% of the total. This indicates that the health science students should not be able to skew the result for the females as they were outnumbered by the total of the other majors.

Although there are not equal numbers for each individual college, the numbers do reflect the total number of students enrolled in these colleges and is a fair representation of the university

as a whole. It was not an intention of the project to aim for equal numbers from each college. If this had been the case then the collection should have been stratified to indicate minimum required numbers from each college prior to starting. It is not thought that the other colleges would differ in any other significant way from each other that would bias the final results.

A check was made statistically for bias by creating a new variable for the college which assigned all students to either health sciences or other colleges. Then the dependant variables of DXA and QUS left heel were compared by t-test. In the males there were only 15 health science students compared to around 100 from other colleges. The t-test result showed no significant difference between groups. In the female group the numbers were almost equal for both QUS and DXA. The t-test could therefore be considered more reliable. There was no significant difference between the college groups for either of the bone strength measures tested suggesting that no bias was evident as health science students do not have better bone strength than their peers in other colleges.

7.3.2.5 Power

The QUS heel groups for the UOS males, UOS females and the group of all females exceeded the number required for the sample to have 80% statistical power. All groups except the DWC group for QUS phalanges exceeded the more conservative sample size calculation which was based on an expected difference in means of 9%.

7.3.2.6 Age

Any possible differences between the younger aged participants, 18 and 19 year olds, and the rest of the group, was investigated. The age range for the study was 18 to 25 which reflects the normal student age. Reference ranges usually start from 20 years of age and therefore it was felt that any difference in bone strength in the younger students should be sought. Hadji *et al* (2002) used an ultrasonometer to measure stiffness, SOS and BUA of the calcaneus in 5,148 German women. SOS was seen to decline from the age of 15 and BUA declined also from late adolescence.

The group of 18 and 19 year olds were separated from the remainder to make two groups and then these two age groups were compared within the main groups of UOS males, UOS females and DWC females. This was then repeated but with just the 18 year olds separated form the rest. In almost all cases the results were that the younger students had higher bone

strength than their older peers, some significantly so. When this finding was explored further by visually inspecting the mean values year by year, the result was the same. As age increased, even within this narrow age range, bone strength often decreased agreeing with Hadji's study.

Before any conclusions were drawn from this finding, checks were made to ensure that these younger volunteers did not differ from the rest in any other way, either their physical characteristics or their risk factor exposure. The risk factors which play the strongest role in influencing bone strength were examined. The only significant difference which was found was in the group of UOS females, where the calcium intake of the under 20 year olds was significantly lower. This should only have lowered their bone strength, not increased it, and therefore was not relevant. The activity score for these females was higher than the older ones but the total number of sports less, which balances out to being the same. All other characteristics matched very well.

A possible theory to explain this phenomenon is that the students become unhealthy when they leave their homes and live on campus. For this to be tested, the question of residence would need to have been asked on the questionnaire as some students do still live in the family home, but it was not. It is the case that campus facilities do not yet provide a supermarket or restaurant. The only nearby restaurants offer fast food such as fried chicken, pizza and burgers. Some of the students commented that they used to regularly drink milk at their mothers insistence but had stopped now that they look after themselves. Comments were also made about exercise being games with other family members at home but not continued at college. It would be interesting to test this theory further in the future and if true would place the onus truly on the educational institute for the well being of the students.

7.3.2.7 Academic Institution

In order to determine whether the DWC females could be added to the UOS females to form one group of all females, the results for each group were compared.

The DWC females were almost 4 centimetres shorter than the UOS females ($p = 0.001$). They were not statistically different in the other categories although weight ($p = 0.113$) was lower without significance. Although there was some difference in characteristics, it is possible to ignore this because in the final analysis BMI was the same for the two groups.

No significant difference was found between the means for any QUS value which indicated that the groups could be combined. In particular, the left heel stiffness was very similar between groups. It will be shown later that this reading best correlates with DXA and therefore is the reading of choice for representing bone strength by QUS of the calcaneum. DXA was not done for DWC females.

The number of phalangeal QUS scans for the DWC group was low and therefore this measure was not as reliable as QUS calcaneum. Again, no significant differences were found between groups. Also, the actual values of AD-SOS, UBPI and BTT are not age matched therefore if the range of ages are different between the groups it would affect the means for QUS even though the mean ages for the two groups was very similar at 20.0 and 20.1 years.

There was a significant difference between the two groups for both measures of physical activity, with the DWC females being more active than the UOS females. However, the DWC females had a lower sun exposure. Only the major risk factors were investigated.

In summary it was decided that any analysis should be performed both on the DWC and UOS females separately and also as one group of all females; four groups in total.

7.3.2.8 Geographical Background

As expected the students were of a variety of nationalities. Only 25% of the males, but about 60% of all the females, were UAE nationals. However 50% of the males and 80% of the females were born in the UAE. Finally, and most importantly, almost 75% of males and 85% of females had spent most of their lives living in the UAE. From this it is known that they were exposed to very similar nutritional and social circumstances. They may have been at the same schools, lived in the same area and eaten the same foods. The hot weather in this country dictates that outdoor sports are very difficult to pursue for most of the year, in fact it is difficult just to walk outside for many of the summer months. Physical exercise in females was reported by the students as low at school.

Nationality was further explored. Apart from UAE nationals, the other nationalities were much smaller in numbers of students. Therefore, it was not statistically possible to test each nationality against each other. Instead, the nationals were compared to the whole group of non-nationals for bone strength to see if there was any difference. This was done both visually

with box plots and then statistically using the student's t-test.

There were 29 male UAE nationals compared to 83 non-nationals whose means appeared to be fairly closely matched. The t-test proved that there was no difference between them with a large p value of 0.357. The data used for performing this test was the QUS value of the lowest heel reading. In the total female group there were 70 UAE females compared to 50 other nationalities. Again, there was no statistical difference between them with a p value of the t-test of 0.149. In each group the difference in stiffness index was 3 units but in different directions. UAE females were lower, males higher, than the non-nationals. If the difference were due to genetics of the UAE race it would be expected to be consistent in both cases, either higher or lower.

7.3.3 Arab Bone Strength

7.3.3.1 Adult Size

This Arab population showed a difference between female bone strength, but not male, and the Caucasian reference data. However, it could be possible that the size of the participants in this study was different to the Caucasian adult size. Looker (2001) stated the size of non-hispanic whites aged 20-49 from data contained in the NHANES III study. Although this is a larger age bracket than that for the current study, of 18-25, it is worth considering the comparison in size. Male whites compared well with Arabs, in height (177.5 to 175.5cm) and weight (82.5 to 80.6kg) but female whites were slightly taller (162.5 to 159.5cm) and much heavier (67.8 to 57.5kg).

The first hypothesis, that Arabic bone strength is different, lower, than the reference value for Caucasians, was tested with the full data for QUS and DXA, males and females. The results are discussed within this section and conclusions drawn. For QUS calcaneum, two sets of results were used – lowest heel and left heel. QUS phalanges T-scores were analysed. The DXA results were analysed on total hip.

All techniques of bone strength have previously been shown to be able to demonstrate bone loss (Grampp *et al*, 1997). This study used QUS primarily because it is completely safe and could be made available on site in a variety of locations. DXA was also used since it is

currently the WHO standard method of determining bone density.

QUS of the phalanges was of questionable use. On analysis, no correlation was found between this technique and any of the other measurements. It has not been used in the market for as long as QUS heel nor have as many studies been performed on it. It has another disadvantage which is that the reference curve detailing the bone strength by age does not peak until later than 20. This meant that several of the participants' actual values would be naturally lower than the older ones as they had not yet reached their peak. The outcome of this is that the actual values could not be used for analysis. To counter this problem the machine gives an age matched value, Z-score, which is the only result that accurately reflected the bone strength between students. But still this value showed no relationship with other bone strength techniques or any of the risk factors it was tested against. One final problem with the equipment is that the results will be falsely low, or underestimated, in larger people because of the added effect of soft tissue in the equation used to calculate SOS and the extra attenuation of sound in the tissues. Strong negative correlation of BMI to AD-SOS proved this to be the case with correlation coefficients of -0.445 ($p = 0.002$) for the males and -0.408 ($p < 0.001$) for females. It was concluded that this technique was not a reliable method of determining bone strength for this population.

Halaba (2005) used the DBM Sonic phalangeal ultasonometer to look for correlation between it and DXA in children and adolescents. Sixty seven girls and 83 aged 14 to 19 boy had and DXA. BMI was found to be negatively correlated with phalangeal QUS in females and overall the study maintained that phalangeal QUS correlated poorly with lumbar spine DXA in young people. In Demark, Alexanderson (2005) focused research on determining the utility of phalangeal QUS at identifying subjects with either low bone density or fracture. This study was considerably larger, with 1,350 60-83 year old postmenopausal women included. Although the QUS parameters did decline with increasing age, the correlation between QUS and DXA was poor ($r = 0.21$, $p < 0.01$). These two papers concur with the results of this study.

7.3.3.2 QUS Calcaneum

QUS calcaneum was extremely useful as a diagnostic tool because it was easy to use, reliable and operator and client friendly. The results appear to be as expected. The distribution followed the normal curve. Four measures were gained for each student. In normal clinical

practice the heel scanned would be in the non-dominant foot. The justification for this is that bone strength clinicians are always looking for the weakest point knowing that bone strength varies from anatomical site to anatomical site around the body. The ISCD (2003) recommends for DXA that if any area shows osteoporosis then the patient is reported as having the condition even though other areas of their body may have normal readings. However, as this was a research study QUS of both heels was performed to see how they compared. Some people are right dominant in their hands and left dominant in their feet or vice versa. Thus asking them which hand they write with may not accurately reflect their dominant foot. Also dominance was self reported and not tested and could have been incorrect. The students were asked about their dominant hand but the analysis has not been performed to find out whether the lowest measurement was from the non-dominant hand. Using the new measurement of lowest heel renders this exercise unnecessary.

Using the two heel results, the average heel reading was computed. The variables for heel QUS then became 1/ right heel stiffness, 2/ left heel stiffness, 3/ average heel stiffness and 4/ lowest heel stiffness. To determine which value was of most importance correlations were performed against DXA. DXA is the recommended method of determining bone strength and therefore the QUS result best matching DXA should be the most appropriate for evaluation. Correlation of QUS heel to DXA was reported in a study of 185 men to be 0.483 (Adler, 2001). This study shows for the males and females the right heel had the lowest correlation with DXA of the total hip. The lowest heel QUS reading and the average QUS heel reading were almost equal in their correlation to DXA but the best correlation for both males and females was the reading for the left heel. The power of the correlation differed between males and females. For the males it was a stronger correlation of 0.583 ($p = 0.001$) and for the females 0.473 ($p = 0.003$). The correlation compares well with the previous research study published by Adler.

The choice of which heel to measure was discussed in an article by Magkos *et al* (2005a) in a study of 1,200 males and females across all age ranges, children to elderly, in Greece. All participants had both heels measured. It was found that the two heel results were not equivalent and that this affected the classification of the individuals fracture risk. The same was true in this study across all four results for the heel. Oral *et al* (2004) agreed that there is a difference between left and right foot measurements and recommended scanning both feet after they studied 621 women with the Sahara ultrasonometer in Turkey.

It was shown in another article by Magkos *et al* (2005b) that in adults there is no difference between genders for heel QUS. This came from a study of 341 adults in Greece using the stiffness result from a Sahara ultrasonometer.

7.3.3.2.1 Males

The mean bone stiffness index for QUS calcaneum of the lowest heel in males was 96.91. There is no reference range for males on the Achilles machine so a comparison to Caucasian males could not be made. However, comparing this result to the Caucasian female reference shows that it is statistically significantly lower by 3%. The standard deviation for males is 15.296. The range for normal QUS based on this population would be from -1 to +1 SD, stiffness index of 81.61 to 112.21. A value of less than 2.5 SD would indicate osteoporosis, a stiffness index of 58.67. No males were classified osteoporotic from the lowest heel reading.

The mean bone stiffness index for QUS calcaneum of the left heel in males is 100.32. There is no reference range for males on the Achilles machine so a comparison to Caucasian males cannot be made. However, comparing this result to the Caucasian female reference shows that it is not statistically different. The standard deviation for males is 16.032. The range for normal QUS based on this population would be from -1 to +1 SD, stiffness index of 84.29 to 116.35. A value of less than 2.5 SD would indicate osteoporosis, a stiffness index of 60.24. No males were classified osteoporotic from the left heel reading.

The four measures of bone strength of the heel produced slightly different results. If the lowest heel value was accepted as being most accurate it would indicate that the males had a 3% lower QUS heel measurement than the female Caucasian reference. However, using the left heel measurement, which best correlates with the DXA results found in this study, the males QUS heel results are the same as the Caucasian female reference range. This agrees with the DXA result which shows the Arab males to have the same DXA results as the Caucasians. If the fact is accepted that young adults have no difference in QUS between genders then it could be concluded that male students have normal bone strength as measured by heel QUS.

From the results published by Shin (2005) of reference data for the Korean population, it can be seen that in the 20-29 age range females QUS SI calcaneum (91.1) was 6% lower than males (96.5). Without t-test values it is not possible to know whether the difference was

statistically significant. The number of participants in each group was also small, 50 males and 55 females but the SI values are similar to this study.

7.3.3.2.2 UOS Females

The mean bone stiffness index for QUS calcaneum of the lowest heel in UOS females is 91.12. There is a reference range for females on the Achilles machine so a comparison to Caucasians can be made. Caucasian females have a mean stiffness of 100.00. Comparing this result to the Caucasian female reference shows that it is statistically significantly lower by 9%. The standard deviation for females is 11.629. The range for normal QUS based on this population would be from -1 to +1 SD, stiffness index of 79.50 to 102.76. A value of less than 2.5 SD would indicate osteoporosis, a stiffness index of 62.06.

7.3.3.2.3 DWC Females

The mean bone stiffness index for QUS calcaneum of the lowest heel in DWC females is 92.85. There is a reference range for females on the Achilles machine so a comparison to Caucasians can be made. Caucasian females have a mean stiffness of 100. Comparing this result to the Caucasian female reference shows that it is statistically significantly lower by 7%. The result is not as low as the UOS females group but the sample size was smaller. A previous t-test between groups showed that their mean values were not statistically different. The standard deviation for females is 13.546. The range for normal QUS based on this population would be from -1 to +1 SD, stiffness index of 79.03 to 106.40. A value of less than 2.5 SD would indicate osteoporosis, a stiffness index of 58.99. The normal range for DWC females is almost equal to UOS females, 79.50 to 102.76, because of the difference in SD.

7.3.3.2.4 All Females

The mean bone stiffness index for QUS calcaneum of the lowest heel in all females is 91.50. There is a reference range for females on the Achilles machine so a comparison to Caucasians can be made. Caucasian females have a mean stiffness of 100. Comparing this result to the Caucasian female reference shows that it is statistically significantly lower by 9%. The standard deviation for all females is 12.042. The range for normal QUS based on this population would be from -1 to +1 SD, stiffness index of 79.46 to 103.54. A value of less than 2.5 SD would indicate osteoporosis, a stiffness index of 61.40. No females would be classified as osteoporotic.

The mean bone stiffness index for QUS calcaneum of the left heel in (only shown in the

results section for all females as the UOS and DWC means were identical) all females is 94.34. There is a reference range for females on the Achilles machine so a comparison to Caucasians can be made. Caucasian females have a mean stiffness of 100. Comparing this result to the Caucasian female reference shows that it is statistically significantly lower by 6%. The standard deviation for all females is 13.201. The range for normal QUS based on this population would be from -1 to +1 SD, stiffness index of 81.139 to 107.541. A value of less than 2.5 SD would indicate osteoporosis, a stiffness index of 61.34. No females would be classified as osteoporotic.

7.3.3.2.5 Summary

It has been mentioned many times that to avoid over diagnosing low bone density the results should be compared to a reference range from the population under investigation. This is reasonable. However, this study, being fairly unique in studying men and women at the same time, has shown the males to have the same result as the Caucasian reference. If it is accepted that in young adults the QUS values would be the same for both sexes then although the females have a lower QUS reading by between 6% and 9%, the Caucasian reference is acceptable because the males match it and the reason for the lower female reading is their lifestyle. This important piece of information further shows that the prevalence of osteopaenia in females under these assumptions is 34% compared to 18% in males.

If, on the other hand, it is accepted that males would have a higher value for QUS bone strength than females then the males cannot be compared to Caucasians since there is no reference. Females are still 6% to 9% less than Caucasians but the argument could be made that this is due to ethnicity. Then it would be reasonable to use their own results as their reference which would effectively reduce the prevalence of osteopaenia for females in their population to 17%.

The first of the two arguments is preferred as it is supported by the females increased risk, over the males, to the important lifestyle risk factors known to lower bone strength as will be discussed later.

7.3.3.3 QUS Phalanges

The Z-scores were presented for QUS phalanges results as these take into account the students age, they are age matched results and can be compared to each other. There was a reference

curve for males and females so the results are also gender matched. In other words, the individual's Z-score explains the position of their measurement compared to another person of the same age and gender. It is interesting then to note that the average Z-score for the males was 0.0371 or just above the average of 0.000 whereas the mean for the females was -0.0153 below the average. QUS phalanges showed a difference of Z-score between the males and females of 0.0524 SD. The prevalence of osteopaenia was consistent between males and females at around 17% just slightly higher than the 15% expected in a normally distributed population.

7.3.3.4 DXA

7.3.3.4.1 Males

The mean bone density for DXA of the total hip in UOS males was 1.037 g/cm^2. There is a reference range for males on the Hologic machine so a comparison to Caucasians can be made. The UAE result is the same as the Caucasian male reference which is found to be 1.037 g/cm^2 on the graph in the results print out from the Hologic equipment.

As the male values match the Caucasian reference data, the criteria for osteopaenia and normal density does not need to be recalculated and the current T-scores stand. This agrees with the finding for QUS (based on male and female QUS readings being the same).

7.3.3.4.2 Females

The mean bone density for DXA of the total hip in UOS females was 0.830 g/cm^2. There is a reference range for females on the Hologic machine so a comparison to the Caucasian mean of 0.943 g/cm^2 can be made. Comparing this result to the Caucasian female reference shows that it is statistically significantly lower by 12%.

The standard deviation for all females DXA is 0.118. The range for normal DXA based on this population would be from -1 to +1 SD, a density of 0.712 to 0.948. A value of less than 2.5 SD would indicate osteoporosis, a density of 0.535. No females would be classified as osteoporotic.

7.3.3.4.3 Summary

For QUS, the male results match the Caucasian reference. The female results are 12% lower than the Caucasian reference. The prevalence of osteopaenia using the Caucasian reference is

54% for the females but only 7% for males.

If the female students own data were used as a reference then the prevalence of osteopaenia would be reduced by 75% to a total of 19% of the students. However this should not be done based on the fact that males are matched in values to Caucasian males.

In DXA, accounting for bone size removes the difference in BMD between males and females. However, the fact remains that females have smaller bones. This is still an issue of concern along with the fact that they are smaller in stature, particularly weight, than white females. Could this also be attributable to poor diet and exercise in childhood and adolescence since the same differences are not seen in male Arabs compared to whites? Changes in bone mass and size are dependent on calcium intake and exercise during childhood growth (Heaney, 2005).

7.3.4 Risk Factors

Risk factors were introduced in chapter 1 and divided into modifiable and non-modifiable. The table of risk factors produced by the National Osteoporosis Foundation detailed the risks. This study aimed to collect information about all of the risks applicable to young adults with the exception of alcohol consumption.

One of the important non-modifiable risks is female gender. Females are at more risk than males for osteoporosis although this stems from their rapid loss of bone strength after menopause and is not relevant in the study of young adults. All other risks would be expected to appear equally in both males and females of the same population. This section will discuss the student exposure to risks for low bone strength and attempt to prove how they have affected bone strength. First the non-modifiable and then the modifiable risks will be presented, following the order that they were introduced in chapter 1.

7.3.4.1 History of Fracture

The maximum number of broken bones suffered by any female was 3 and for the males twice as many. The mean number of broken bones was also twice as many for males than females. This could be due to the fact that females are only minimally physically active. The distribution of the data for number of fractures was not normal therefore non-parametric tests

were used in analysis.

Sustaining a fracture from a minimum force trauma is called a fragility fracture. Students were asked how many fractures they had suffered and also whether they considered any of them to be fragility fractures. Surprisingly some of the students answered that they did feel they had suffered a fragility fracture. A fragility fracture is usually an indicator of extremely low bone strength therefore a relationship was expected between fragility fracture and low bone strength. Secondly, increasing numbers of fractures could be linked to lower bone strength and so this relationship was also tested in the data with correlation analysis.

The percentage of students reporting fragility fractures is shown in the results to be 14% for males and 18% for females. Odds ratios give the relative chance of having low bone density in the presence of a risk compared to when the risk is not present. Odds ratios, for students reporting a fragility fracture compared to those without one, were produced and showed that for all students (males and females together) those with fragility fractures were 3.4 times (confidence interval CI 0.900 – 12.941) more likely to have low bone strength on QUS than normal. When the DXA results were analysed, the likelihood of having low density increased to 4.1 (CI 0.520 – 32.750) but without significance. The odds ratio of low QUS/normal for the males was 4.5 with a fragility fracture (CI 0.459 – 45.035), for UOS females it was 2.5 (CI 0.511 – 12.222) and for all females 2.7 (CI 0.538 – 13.556).

Correlation between bone strength and the number of broken bones was measured with the Spearmans correlation coefficient test. Number of fractures showed a correlation with many other variables. Firstly, negative correlations to bone strength measures were significant for both QUS and DXA for the total group of students. It was strongest for DXA of the intertrochanteric region, rho = -0.236 ($p = 0.051$), indicating that as bone density increased, the number of fractures decreased. The correlation is weak but could be caused by the range of number of fractures being very small.

Number of fractures correlated positively ($p < 0.05$) with all measures of sport activity, sun exposure and with IPAQ score ($p = 0.060$) with coefficients around rho = 0.125. It also correlated positively with measures of smoking, caffeine and carbonated drink consumption with coefficients all in the range of rho = 0.133 to 0.145. The link with sport and activity could be that the more active a person is the more likely they are to have a fracture. However,

the link with caffeine, carbonated drinks and smoking could be evidence of their importance in risk to bone strength.

Regression analysis aims to discover which factors independently predict the outcome, which in this case is low bone strength. In a regression model for DXA scans on males the number of broken bones independently predicts bone density. For each broken bone the bone density of the individual is reduced by 0.236 g/cm^2 ($p = 0.086$), a reduction of 23%.

In summary, for the group of students as a whole there is evidence that having sustained a fragility fracture the student is 3.4 times (CI approaching statistical significance) more likely to have low bone strength which indicates a link between fragility fracture and low bone strength. The lower the bone strength of a student, the more fractures they sustained confirming that weaker bones break more easily in this population of young Arab students. In males, fractures independently predict bone density DXA results.

7.3.4.2 Low BMI

At 24.6, the BMI of the males was at the upper end of the range considered normal weight (20–25). The female groups all had mean BMI values in the middle of the normal range. The distribution of BMI values was normal but in the female group it was slightly skewed to the right with more of the lower values. This was caused by some students being underweight for their height in the UOS female group. The DWC females were lighter and shorter than the UOS females but their weights better matched their heights and thus their BMI distribution was not skewed. Students with severe obesity, a BMI over 35, were excluded.

From the clustered bar chart for BMI of all groups, it can be seen that both female groups had much higher percentages of underweight students than the males. A BMI of less than 20 is considered a risk factor for low bone strength because the skeleton needs to do work carrying a load in order to maintain its health. The bone reacts to load carrying by remodeling itself and ensuring its integrity as a strong, mechanical structure.

When odds ratios were produced for either low QUS/normal or low DXA/normal there was a considerably increased chance of having low bone strength if the student was underweight.

Testing the whole group of males and females together, an underweight student was 1.6 times more likely to have low QUS bone strength (CI 0.980 – 2.597) and 3.1 times more likely to be osteopaenic on DXA (CI 1.341 – 6.947). Investigating males and females separately showed DXA results for underweight males and females were very likely to be osteopaenic but without statistical significance, probably due to the smaller sample sizes. For QUS, which was performed on much larger numbers of students, and in the female group with a much higher percentage of underweight students, they were almost twice as likely to have low bone strength (CI 1.093 – 3.284).

ROC curves also showed a relationship between low BMI and low bone strength for heel QUS and hip DXA. In the female group, the cut point for determining that the outcome changed from low QUS to normal was a BMI of 20. For all students as a group and for males and females independently, the cut point for a result of normal DXA was a BMI of 21. These results agree with the published data of low BMI being a risk for low bone strength. QUS of the phalanges for the UOS females gave a contradictory result. A BMI of over 19 was indicative of osteopaenia. This is assumed to be because this technique underestimates bone strength values with increasing amounts of soft tissue. Reversing the relationship between BMI and bone strength, which is shown with the other two techniques, renders this phalangeal QUS equipment unreliable and undesirable as a screening tool for this population.

The final support for the link between osteopaenia and low BMI came from regression analysis. BMI correlated with the DXA result in the male group. Only 14% of males were underweight. For the females, the results were that BMI correlated with QUS lowest heel at rho 0.277 ($p = 0.001$) and with DXA hip at rho 0.444 ($p = 0.005$). BMI showed correlation with all measures of QUS heel and DXA ($p < 0.03$). Independently, in a regression model for female QUS heel, BMI accounted for some of the variation in stiffness (Beta 0.237, $p = 0.003$). For DXA of the hip in males an increase of 1 BMI unit increased the DXA value by 0.374 g/cm2 ($p = 0.009$) or 36%. DXA of the hip in females increased by 0.467 g/cm2 ($p = 0.001$) or 56% for 1 unit of BMI.

In summary, this research shows good evidence of low bone strength in students who are underweight, both in bone quality as measured by QUS and in bone density as measured by DXA. Before moving to the next section, it is worth noting that when BMI was checked for correlation it showed a relationship with some of the other risk factors. In males, BMI

correlated positively with the number of milk drinks per week with a rho value of 0.212 (p = 0.020) and negatively with sun exposure rho -0.182 (p = 0.047). In the female group, BMI correlated with the number of milk drinks per week with a rho value of 0.168 (p = 0.026) and negatively with menarche age rho -0.229 (p = 0.002). The relevance of these correlations are that for regression analysis there should not be any collinearity between factors entered into the model which means that the risk factors which correlate with BMI cannot be tested in a regression at the same time as BMI.

The link with BMI and milk could indicate that those students watching their weight avoid milk. Increased BMI and less sun exposure could be due to lack of exercise since being more active usually involves some outdoor pursuit, even if just walking around the campus. Also, females who are younger when menstruation starts have higher BMI values which are possibly caused by the natural progression of puberty and shape change which coincides with this time.

7.3.4.3 Nil or Minimal Physical Exercise

Physical activity was measured in a number of ways. For the 120 males the average amount of sports activity per week was 4.6 hours, which was 5 times the amount the females spent at 0.9 hours. The IPAQ score was calculated to measure active time during a week. The males average IPAQ score was 3,043 units but the females just over half that amount at 1,733. The histograms in the results section demonstrate the lack of activity by the majority of the females. In order to assign a category representing students at risk from low activity, the IPAQ scores were graded as inactive, moderate activity and active. The percentage of students in each of these categories can be seen on a clustered bar chart which indicates the difference in activity between the males and females clearly. Only a minority of males reportedly were inactive, 8%. Low sports was a category where the number of sports units per week was less than 4 i.e. less than 1 hour per week.

Odds ratios showed that for all students as one group, both low sports level and low activity increased the chance of having osteopaenia. For QUS heel the risk of having low QUS/normal was 1.396 (CI 1.115 – 1.749) when the sports level was low. For DXA the risk of having low DXA/normal was 1.513 (CI 1.056 – 2.169) with a low level of sports and 2.747 (CI 1.176 – 6.414) with low activity. It is natural that low activity causes a much higher risk than low sports because people can be active without participating in sports but a low IPAQ category indicates very little activity of any kind including walking or standing. In the group of males

those who performed low levels of sports were 1.8 times (CI 1.014 – 3.195) more likely to have low QUS heel. In the female groups the results did not reach significance probably because there were so few females without the risk.

ROCs further confirmed that low sports or activity indicates low bone strength. For all students if they performed more than 45 minutes of sports per week they were more likely to have normal QUS heel values and if they reported more than 820 IPAQ units they were more likely to have a normal DXA result.

Correlation analysis did not yield any positive results in the male group which could be because only 8% of males were inactive. Almost all males performed enough physical exercise to ensure healthy bones. The females were very different. Several correlations were shown between activity and bone strength, most notably total units of sport per week to left heel stiffness rho 0.197 ($p = 0.015$) and activity code to DXA hip rho 0.343 ($p = 0.035$). The total unit of sport per week was the only independent predictor of QUS heel in the male group but showed a small effect on the stiffness value, approaching significance. The females were the same for QUS. For DXA the males showed no correlation with sports or exercise. The females had a positive correlation between DXA and activity code but activity code showed colinearity with BMI and could therefore not be entered into the regression model.

In summary, females were minimally active compared to males and showed a much higher incidence of osteopaenia. Links were shown to suggest the effect of exercise on bone strength but the two groups were at each end of the spectrum in terms of exercise, the males almost all exercised through some type of sport and the females mostly performed no sport. Without normal ranges within each group associations were not visible. Further research into this area would be useful to clarify the situation further, particularly an experimental approach monitoring females who exercise against a matched group who do not.

7.3.4.4 Low Calcium Intake

In the section on descriptive statistics it can be seen that the average calcium intake per day for males was 722 mg, similar to the females at 631 mg. These amounts are far below the recommended daily intake of 1200 mg. In addition to calculating the amount of calcium per day, the number of milk drinks per day was questioned. The results of both of these measures correlated well with each other, in all students the correlation was rho 0.384 ($p < 0.001$),

suggesting that milk accounts for a substantial amount of the calcium intake of students.

In the results section on exposure to risk the clustered histogram for calcium risk shows that the majority of all students are at risk from low calcium intake – over 80% of every group. Low calcium had more impact on DXA than QUS. In the odds ratios for all students a result of low DXA/normal was 1.246 times more likely when the students calcium intake was low (CI 1.038 – 1.496). This was supported by the ROC for calcium intake which indicated that an intake of 420 mg calcium was the cut point where the DXA result changed from being low bone density to normal. For males, calcium intake was shown in a regression model to independently predict bone density.

In summary, evidence from this research project points to the importance of adequate calcium intake in ensuring normal bone strength through odds ratio, ROC and regression analysis however this area needs further evaluation because in this population more than 80% had insufficient calcium intakes of around half the recommended daily amount. The full effect of adequate calcium intake therefore was hard to measure because of the low number of students fulfilling the requirement. As with exercise, a new study with calcium supplement would be beneficial.

7.3.4.5 Smoker

Almost no females smoked and so the effect of smoking on bone strength of females could not be ascertained. In the male group 46 out of 120 were smokers, approximately 40%. Neither the odds ratios nor the ROCs showed any evidence of links between smoking and bone strength. Smoking is thought to be a more minor influence than the other risk factors and previous results from other studies have been ambiguous. Also, perhaps the beneficial effect of adequate exercise outweighed any damage done through smoking.

7.3.4.6 High Caffeine or Carbonated Drink Consumption

The amounts of caffeine and carbonated drinks consumed by the males were far higher than the females. Males average caffeine intake per week was 1,075 mg compared to 642 for the females. Males drank 10 carbonated drinks per week on average and the females only 5. Caffeine intake and carbonated drinks were strongly correlated to each other, rho 0.504 ($p < 0.000$) indicating that much of the caffeine consumed comes from carbonated beverages. Risks for these variables were classified as more caffeine than the equivalent of 3 cans of cola

per day (> 714 mg / day) and more than three carbonated drinks per day. Clustered bar charts show that 60% of males had a caffeine risk compared to approximately 30% of females but for carbonated drinks very low numbers of students were at risk.

For males who had a high caffeine risk the DXA was 1.933 times (CI 1.360 – 2.748) more likely to be osteopaenic than normal. For females the odds ratios did not reach statistical significance. Males showed no correlation between either of these variables and measures of bone strength. Females however had a negative correlation between carbonated drinks and right heel stiffness though fairly weak.

In summary this project did not demonstrate clear evidence of risk of low bone density from either high caffeine intake or high carbonated drink consumption.

7.3.4.7 Oestrogen Deficiency

Oestrogen in females was monitored by questioning the age at onset of menarche and menstrual regularity. The average age of menarche was 13 and only approximately 2% of students reported menstrual irregularity therefore none of the group was at risk from late menarche and a minimal number from irregular menstruation. However in odds ratio analysis an increased chance of low QUS heel approached statisitical significance.

Menstrual regularity, from 1 for normal to 3 for irregular, negatively correlated to DXA of the hip at rho -0.309 ($p = 0.059$) indicating that less regular menstruation lowers bone density. Numbers of students in the irregular category were very small which lowers the power of the analysis.

7.3.4.8 Sun Exposure

The average time that the males in the study were exposed to the sun per day was 88 minutes and for the females the average was 51 minutes. The minimum sun exposure required to maintain adequate production of vitamin D is 15 minutes so on average both the males and females exceeded the minimum requirement. However, some students did report less than 15 minutes. The histograms show the distribution of the results for this variable and the clustered bar charts show the percentage of students in the risk category of low sun exposure, highest for UOS females at 37%.

For all students, the odds ratios analysis showed that students with low sun exposure were 1.523 times (CI 0.955 – 2.431) more likely to have a low QUS heel reading and 3.205 (CI 1.302 – 7.885) times more likely to have osteopaenia on DXA. Similar results were seen within the individual groups but without significance.

The ROC results were conclusive in agreeing with published levels of risk as the cut point for determining normal DXA for the whole group of students was 15 minutes. Correlations were examined for sun exposure against all other variables. Male sun exposure only negatively correlated with BMI. Female sun exposure correlated with DXA of the hip, rho 0.288 ($p = 0.079$) and with the IPAQ score, rho 0.285 ($p < 0.000$). The correlation to IPAQ suggests that a certain amount of daily activity involves going outside since the campuses are large and require walking outdoors from one building to another. Students who are very inactive also fail to get outside for sufficient sun exposure. Because sun exposure correlated with other variables it could not be entered into the regression models.

In summary, odds ratios indicated an increased risk of low bone strength with inadequate sun exposure which is twice as serious for DXA than QUS. ROC analysis agreed, with a minimum required time in the sun of 15 minutes for normal bone strength.

7.3.5 Evaluation of Full Study

7.3.5.1 Measurement Techniques

The Achilles QUS heel ultrasonometer performed well as did DXA but the DBM Sonic gave results which neither correlated to any risk factors nor the other two bone measurement techniques. It was felt that this technique was unreliable. Perhaps this was due to lack of skill in the operator as the technique was more difficult to perform however full training was received prior to equipment use. Another explanation could be the anatomical site. There is a difference between measurement sites as the phalanges are non-weight bearing but the hip and heel strength results reflect weight carried and exercise impact. Had this equipment been chosen as the only method of measuring bone strength the results would have to be accepted and the outcomes of the research would have been completely different. Having two other measures for comparison demonstrated this technique to be incorrectly measuring bone strength.

7.3.5.2 Lifestyle Instrument

The lifestyle tool fulfilled its duty of revealing information regarding the variables under observation. Cross correlation of some variables, with multiple questions, appeared to confirm validity of the answers.

7.3.5.3 Strengths and Weaknesses of Full Study

One of the most important points about this study is that it reveals information about the UAE population which has never been examined before, both for males and expatriate Arab females who were investigated for the first time. The number of students enrolled in the study was large, which increased the power of the analyses performed.

The weaknesses were as follows:

1/ this research was performed by one individual researcher with an assistant and future research would benefit from a team of researchers working together in order to improve study design and handle more volunteers,

2/ DXA was limited in number because it is was located far from the campus and this could be greatly improved if Al Qassimi Hospital in Sharjah acquired a DXA scanner which may happen in the near future as they have it on their list of required equipment,

3/ the time frame for performing DXA scans was too short and would have benefited from beginning at the same time as QUS thus running throughout the whole semester,

4/ all results were self reported and could have been checked further through retesting some students after a gap of perhaps a week, and

5/ a question about domicile to discover whether students looked after themselves or lived at home would have been an interesting addition to the study in case those living away from home differed in exposure to risk from those looked after by their parents.

7.3.6 Future Research

7.3.6.1 MRI Heel

MRI was included in this project as a pilot investigation for future studies. There was no difficulty in obtaining volunteers from those who had already undergone DXA. 11 scans were performed, 6 males and 5 females. It was intended that some students with low and some with high QUS heel values would be selected. They were informed that no measurements could be

performed on the MRI scans immediately and that they would not gain any further knowledge of their bone strength at this stage. The selection of students was made only from those who had completed DXA.

7.3.6.1.1 Descriptive Statistics

Descriptive Statistics[a]

	N	Minimum	Maximum	Mean	Std. Deviation
age	6	18	25	21.83	2.563
Body Mass Index (BMI) kg/m2	6	20	32	26.12	4.303
QUS heel	6	62	102	79.00	13.943
DXA g/cm2 Total hip	6	.884	1.192	.96667	.115868
Valid N (listwise)	6				

a. Sex = Male

Table 52 Descriptive statistics MRI students, males

Descriptive Statistics[a]

	N	Minimum	Maximum	Mean	Std. Deviation
age	5	18	23	20.40	1.817
Body Mass Index (BMI) kg/m2	5	18	29	22.57	4.156
QUS heel	5	73	108	93.20	14.307
DXA g/cm2 Total hip	4	.745	.887	.79875	.064479
Valid N (listwise)	4				

a. Sex = Female

Table 53 Descriptive statistics MRI students, females

In the males group the average heel stiffness was actually low, although the highest was 102. In the female group the range was better, from 73 to 108.

7.3.6.2 MRI Heel Scans

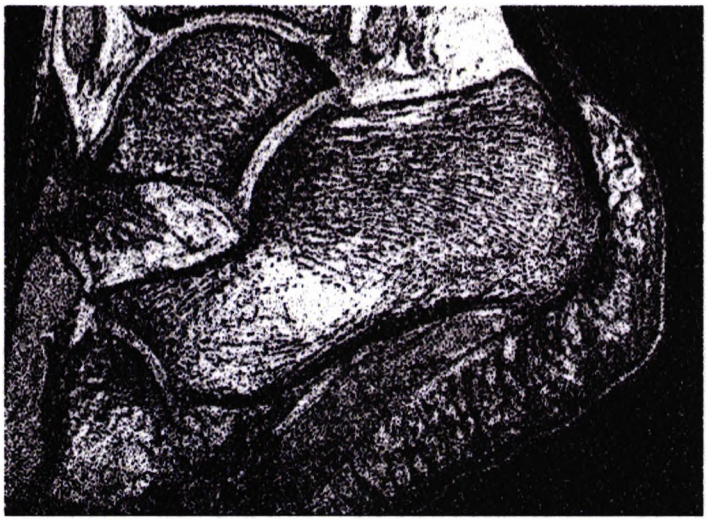


Figure 98 MRI heel, QUS stiffness 108

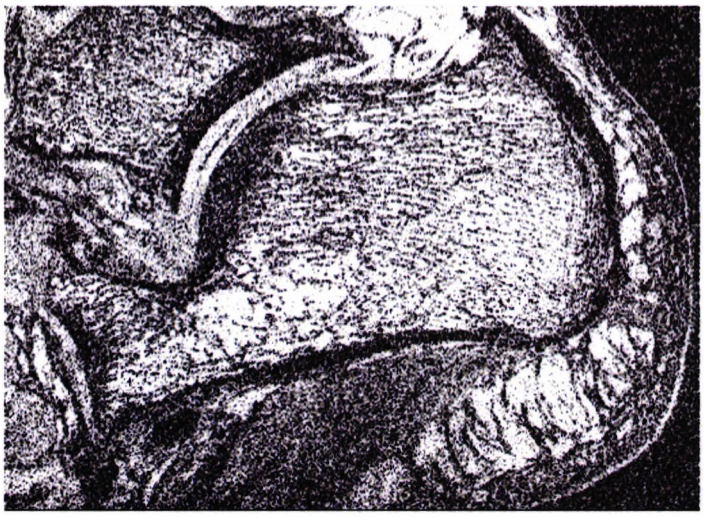


Figure 99 MRI heel, QUS stiffness 62

The MRI scans pictured are from the lowest and highest values of heel QUS. White represents marrow and black indicates bone.

7.3.6.3 MRI analysis

This kind of image, displayed above, is possibly the key to fully understanding bone quality since with processing it can reveal not only the bone mass in a volumetric area but also information about the structural integrity of the bone. The images were fairly simple to perform although the pre scan process is time consuming. The actual scan time is also very long at approximately 30 minutes altogether including positioning scans. The main problems

with MRI are accessing the machine as it is always fully utilized by a busy hospital, and the cost. These research scans were only possible by opening the department over the weekend. However, the promise of the information to be revealed from full processing would seem to justify the effort.

7.3.6.4 Next Study

This study has opened the door to understanding the habits of young adults in the UAE and has been enlightening regarding the huge difference in behaviour of males and females. To follow on from the discoveries made here, more work is needed to explore further the prevalence of osteopaenia in females. Since males do not suffer to the same degree then perhaps this is because they perform adequate physical exercise but to test this further an experimental study would be beneficial. Students could be enrolled in a control group if they are minimally active and alternatively in a test group if they agree to a programme of exercise. There is now a female sports complex on campus which could be used for this purpose. The study would be longitudinal over a time frame of 1 to 2 years aiming to detect an improvement in bone strength with exercise.

The other direction that future research in this population should take is to further study the characteristics of bone through MRI imaging. As described above, a few selected participants were scanned with a third imaging modality (Magnetic Resonance Imaging) during this project. The scans have been sent to Dr Dean Inglis, McMaster University, Canada regarding the possibility of structural analysis. The MRI images performed during this study as a pilot showed that obtaining the images at the quality level required is possible. Next the capability to process and examine the images must be acquired in order to explore bone parameters. Since there are such differences between males and females, and high numbers of females with osteopaenia, UAE young adults would be an ideal group to study in this way.

If the analysis is successful then a further UOS grant would be requested to study a group of inactive and a group of active young males and females with QUS and MRI, sending the MRI scans to Canada for interpretation. Activity would be defined as regular participation in a sport for a minimum of 2 years. Recruitment could be from a sports club such as horse riding or martial arts, both of which are popular in the UAE with males and females. It is hoped that through collaboration with experts in Canada that this goal may be achieved in the near future.

8. CONCLUSION

8.1 Conclusions

8.1.1 Bone strength

The first hypothesis, that Arabic bone strength is different, lower, than the reference value for Caucasians, was tested with data for QUS and DXA, males and females. All techniques of bone strength have previously been shown to be able to demonstrate bone loss. This study used QUS primarily because it is completely safe and could be made available on site in a variety of locations. DXA was also used since it is currently the WHO standard method of determining bone density.

It has been mentioned many times that to avoid over diagnosing low bone density the results should be compared to a reference range from the population under investigation. This is reasonable. However, this study, being fairly unique in studying men and women at the same time, has shown the males to have the same result as the Caucasian reference for both QUS and DXA whilst the females were 9% lower for QUS and 12% for DXA. If it is accepted that in young adults the QUS values would be the same for both sexes then although the females have a lower QUS reading by 9%, the Caucasian reference is acceptable because the males match it and the reason for the lower female reading is their lifestyle. This is a significant point if accepted since currently the assumption has been made that Arab bone strength is genetically lower than Caucasian, thus accepting the lower values as normal when they may be abnormal and due to lifestyle.

8.1.2 Lifestyle risk factors

One of the important non-modifiable risks for low bone strength is female gender. Females are at more risk than males for osteoporosis although this stems from their rapid loss of bone strength after menopause and is not relevant in the study of young adults. All other modifiable risks would be expected to appear equally in both males and females of the same population.

At 24.6, the BMI of the males was at the upper end of the range considered normal weight (20–25). The female groups all had mean BMI values in the middle of the normal range. The distribution of BMI values was normal but in the female group it was slightly skewed to the right with more of the lower values. This was caused by some students being underweight for their height in the UOS female group. A BMI of less than 20 is considered a risk factor for

low bone strength because the skeleton needs to do work carrying a load in order to maintain its health. The bone reacts to load carrying by remodeling itself and ensuring its integrity as a strong, mechanical structure. Odds ratios and ROC curves indicated the association of low BMI to low bone strength.

Almost all males performed enough physical exercise to ensure healthy bones. Odds ratios showed those who did not perform enough sport were 1.8 times more likely to have low bone strength. The females were very different. Their physical activity and sport activity values were extremely low compared to males.

The average calcium intake per day for males was similar to the females. These amounts are far below the recommended daily intake of 1200 mg. This is an area which deserves further investigation as female ROC analysis showed the value in increased bone strength on DXA in parallel with increased calcium intake. In general, all risk factors showed a trend towards causing increased risk of low bone strength although some without statistical significance.

This research highlights the fact that bone strength in Arab adults requires further study to understand better whether the lower bone strength seen in females is actually genetic or whether it is in fact merely a side effect of unhealthy lifestyle. Current treatment and advice is possibly ineffective if it does not address the whole problem, creating a large prospective prevalence of osteoporosis – the silent disease.

REFERENCES

CASES

Adler, C-P. , (2000)
Bone Diseases.
Berlin: Springer-Verlag. 30, 31

Adler, R. A. , Funkhouser, H. L. & Holt, C. M. (2001).
Utility of heel ultrasound bone density in men.
Journal of Clinical Densitometry 4 (3): 225-230. ..... 134, 226

American Medical Association. (1999)
Continuing Medical Education Program: Managing Osteoporosis.
(AMA CMA Program for Primary Care Physicians)
Available online.
Accessed on 12 January 2001 ..... 47, 83, 91

Anonymous, (1993)
Consensus development conference: diagnosis, prophylaxis, and treatment of osteoporosis.
American Journal of Medicine 94:646 28

ArabNet. (1996)
UAE Government: Health.
(ArabNet, online)
Available at: http://www.arab.net.uae/govt/ue_health.html
Accessed on 17 January 2001 51

Ardawi, M. S. , Maimany, A. A. , Bahksh, T. M. , Nasrat, H. A. , Milaat, W. A. & Al Raddadi, R. M. (2004).
Bone mineral density of the spine and femur in healthy Saudis.
Osteoporosis International May: e publication. 212

Arokoski, M. H. , Arokoski, J. P. , Vainio, P. , Niemitukia, L. H. , Kroger, H. & Jurvelin, J. S. (2002).
Comparison of DXA and MRI methods for interpreting femoral neck bone mineral density.
Journal Clinical Densitometry 5 (3): 289-296. 106

Asch, E.S. (1998)
Osteoporosis: A new era.
Rheumatology & Musculoskeletal Medicine for Primary Care 1 (2): 3-5. ..... 22, 47, 48

Bauer, D. C. , Gluer, C. C. , Cauley, J. A. , *et al* (1997).
Broadband ultrasound attenuation predicts fractures strongly and independently of densitometry in older women. A prospective study.
Archives of Internal Medicine 157: 629-634 ..... 85, 103, 106

Bererhi, H. , Constable, A. , Lindell, S.E. , Coutino, J. and Kharousi, W. (1994)
A Study of Bone Mineral Density Versus Age in Omani Women and a Comparison with Normal British Women.
Nuclear Medicine Communications 15 (2): 99-103. ..... 37, 69

Bonnick, 2004, p2 ..... 82, 91, 92

Bonnick, S. L. (2004), pp 160-165
Bone Densitometry in Clinical Practice. Application and Interpretation. 2nd Ed
New Jersey: Humana Press 56, 82

Bonofiglio, D. , Maggiolini, M. , Marsico, S. , Giorno, A. , Catalono, S. , Aquila, S. and Ando, S. (1999).
Critical Years and Stages of Puberty for Radial Bone Mass Apposition During Adolescence.
Hormone Meatbolism Research 31 (8): 478-482 73

Boutry, N. , Cortet, B. , Dubois, P. , Marchandise, X & Cotten, A. (2003)
Trabecular Bone Structure of the Calcaneus: Preliminary in Vivo MR Imaging Assessment in Men with Osteoporosis
Radiology 227:708-717 109

Boutry, N. , Cortet, B. , Dubois, P. , Marchandise, X. & Cotten, A. (2003).
Trabecular bone structure of the calcaneus: preliminary in vivo MR imaging assessment in men with osteoporosis.
Radiology 227 (3): 708-717. ..... 107, 109

Bowers, D. , House, A. & Owens, D. (2001) p59.
Understanding clinical papers.

(Chichester: Wiley)..... 136
Buckley, L. M. (1998)
Osteoporosis: Prevention and Management of Osteoporosis.
Rheumatology & Musculoskeletal Medicine for Primary Care 1 (2).
Available at: http://www.rheumatology.org/publications/primarycare/number2/hrh0010298.html
Accessed on 24 October 2001 ..... 55, 56, 58
Burlet, N. & Reginster, J. Y. (2006)
Strontium Ranelate: the First Dual Acting Treatment for Postmenopausal Osteopososis.
Clinical Orthopaedic Research 443:55-60. 57
Cadogan, J. , Eastell, R. , Jones, R. & Barker, M. E. (1997).
Milk intake and bone mineral acquisition in adolescent girls: randomised, controlled intervention trial.
British Medical Journal 315: 1255-1260. ..... 73, 74
Cheng, S. , Njeh, C. F. , Fan, B. , Cheng, X. , Hans, D. , Wang, L. , Fuerst, T. , Genant, H. K. (2002).
Influence of region of interest and bone size on calcaneal BMD: implications for the accuracy of quantitative ultrasound assessments at the calcaneus.
British Journal of Radiology 75: 59-68. 103
Chestnut, C. H. , Silverman, S, Andriano, K. *et al* (2000)
A Randomized Trial of Nasal Spray Salmon Calcitoninin Postmenopausal Women with Established Osteoporosis: The Prevent Recurrence of Osteoporotic Fractures Study.
American Journal of Medicine; 109:267-276. 56
Compston, J. (1999)
The British Medical Association Family Doctor Guide to Osteoporosis.
(London: Dorling Kindersley Limited)..... 40, 55, 56, 57
Compston, J.E. (1992)
Risk factors for osteoporosis.
Clinical Endocrinology 36: 223-224. 45
Cooper, C. , Eriksson, J. G. , Forson, T. *et al* (2001).
Maternal height, childhood growthand risk of hip fracture in later life: a longitudinal study.
Osteoporosis International 12: 623-629..... 45
Cummings, S. R. , Black, D. M. , Thompson, D. E. *et al* (1998)
Effect of Alendronate on Risk of Fracture in Women with Low Bone Density but without Vetebral Fractures.
Lancet; 348:1535-1541..... 56
Cummings, S. R. , Nevitt, M. C. , Browner, W. S. , Stone, K. , Fox, K. M. *et al* (1995)
Risk Factors for Hip Fracture in White Women. Study of Osteoporotic Fractures Research Group.
New England Journal of Medicine 332:767-773. 67
Curry,T. S. , Dowdey, J. E. & Murry, R. C. (1990)
Christensen's Physics of Diagnostic Radiology
Philadelphia: Williams & Wilkins..... 106, 108
Daniel, W. W. (2000).
Biostatistics: A foundation for analysis in the health sciences.
(London: Wiley). 118, 120
Delmas, P. D. , Bjarnason, N. H. , Mitlak, B. H. *et al* (1997).
Effect of Raloxifene on Bone Mineral Density, Serum Cholesterol Concentrations, and Uterine Endometrium in Postmenopausal Women.
New England Journal of Medicine; 337:1641-1647. 57
Desouki, M (2005)
Personal Communication
Professor, King Saud University, Riyadh, KSA 20
Diamond, T. H. , Thornley, S. W. , Sekel, R. and Smerely, P. (1997)
Hip fracture in elderly men: prognostic factors and outcomes.
(eMJA, online)
Available at: http://www.mja.com.au/public/issues/oct20/diamond/diamond.html
Accessed on 04 December 2005..... 70
Duckworth, T. (1995)
Orthopaedics and Fractures
(Oxford: Blackwell Science) 36
Eastell, R. , Boyle, J. , Compston, J. , Cooper, C. , Fogelman, I. , Francis, R.M. , Hosking, D. J. , Purdie, D. W. *et al* (1998).
Management of male osteoporosis: report of the UK consensus group.
Q J Med 91: 71-92..... 70
El Abbass, H. (2002)

Head of Radiology, Sharjah and Northern Emirates, Personal Communication..... 60
Elgan, C. , Samsioe, G. & Dykes, A. K. (2003).
Influence of smoking and oral contraceptives on bone mineral density and bone remodelling in young women: a 2 year study.
Contraception 67 (6): 439-447. 72
Ettinger, B. , Black, D. M. , Mitlak, B. H. *et al* (1999).
Reduction of Vertebral Fracture Risk in Postmenopausal Women with Osteoporosis Treated with Raloxifene. Results from a 3 Year Randomized Clinical Trial.
Journal of the American Medical Association; 282:637-645. 57
Faulkner, K. G. , von Stetten, E. & Miller, P. (1999).
Discordance in patient classification using T-scores.
Journal of Clinical Densitometry 2 (3): 343-350. 100
Frame, P. S. & Carlson, S. J. (1975)
A critical review of periodic health screening using specific screening criteria. Part 1: Selected diseases of respiratory, cardiovascular, and central nervous systems.
Journal of Family Pract. (1):29-36..... 47
Frost, M. L. , Blake, G. M. & Fogelman, I. (2001).
Quantitative ultrasound and bone mineral density are equally stongly associated with risk factors for osteoporosis.
Journal of Bone Mineral Research 16 (2): 406-416. 100
Genant *et al*, (1996)
Advances in the noninvasive assessment of bone density, quality, and structure.
Calcified Tissue International;59 S1:10-15 134
Gennari, C. , AgnusDei, D. , Gonelli, S. and Nardi, P. (1989)
Effects of Nanrolone Decanoate Therapy on Bone Massand Calcium Metabilism in Women with Established Post Menopausal Osteoporosis: a Double Blind Placebo Controlled Study.
Maturitas (11) : 187-197..... 57
Gerdham, P. , Obrant, K. J. (2004)
Bone Mineral Density in Old Age: the Influence of Age at Menarche and Menopause.
Journal of Bone Mineral Metabolism 22 (4):372-375. 73
Ghannam, N.N. , ,Hammami, M.M. , Bakheet, S.M. and Khan, B.A. (1999)
Bone Mineral Density of the Spine and Femur in Healthy Saudi Females: relation to vitamin D status, pregnancy, and lactation.
Calcified Tissue International 65 (1): 23-28..... 37, 69, 212
Gluer *et al* (1990)
Comparative assessment of dual-photon absorptiometry and dual-energy radiography
Radiology;174(1):223-228 69
Gluer, C. C. (1997)
Quantitative ultrasound techniques for the assessment of osteoporosis: expert agreement on current status. The International Quantitative Ultrasound Consensus Group.
Journal of Bone Mineral Research;12(8):1280-1288 134
Gomberg , B. R. , Saha, P. K. , Song, H. K. , Hwang, S. N. & Wehrli, F. W. (2000).
Topological analysis of trabecular bone MR images.
IEEE Trans Med Imaging 19 (3): 166-174..... 107
Grainge, M. J. , Coupland, C. A. , Cliffe, S. J. , Chilvers, C. E. & Hosking, D. J. (1998).
Cigarette smoking, alcohol and caffeine consumption, and bone mineral density in postmenopausal women. The Nottingham EPIC study group.
Osteoporosis International 8 (4): 355-363..... 72
Grampp, S. *et al* (1997)
Comparisons of noninvasive bone mineral measurements in assessing age-related loss, fracture discrimination, and diagnostic classification.
Journal of Bone and Mineral Research 12 (5): 697-711..... 99, 224
Gulf News (2005)
Vertebroplasty
Anonymous..... 58
Guyton, (1982) p566.
Human Physiology and Mechanisms of Disease, 3rd Ed.
(Philidelphia: Saunders International) 36
Guyton, A. C. (1982)
Human Physiology and Mechanisms of Disease
(Philadelphia: Saunders)..... 33

End Matters

Hadji, P. , Kalder, M. , Backhus, J. , Gottschalk, M. , Hars, O. & Schulz, K. D. (2002)
Age-associated Changes in Bone Ultrasonometry of the Os Calcis.
Journal of Clinical Densitometry 5 (3):297-303. 221

Halaba, Z. P. , Konstantynowicz, J. , Plukiewicz, W. , Kaczzmarski, M. & Piotrowska-Jastrzebska, J. (2005)
Comparison of Phalangeal Ultrasound and Dual Energy X-ray Absorptiometry in Healthy Male and Female Adolescents.
Ultrasound Medicine and Biology 31(12):1617-1622. 225

Heaney, R. P. & Weaver, C. M. (2005)
Newer Perspectives on Calcium Nutrition and Bone Quality.
Journal of American College Nutrition 24 (6):574S-581S. 231

Henry, C. J. , Lightowler, H. J. and Hourani, H. M. (2004)
Physical Activity and Levels of Inactivity in Adolescent Females Ages 11-16 Years in the United Arab Emirates.
American Journal of Human Biology; (3):346-353. 79

Ilich, J. Z. and Kerstetter, J. E. (2003)
Nutrition in bone health revisited: a story beyond calcium. 75

International Society for Clinical Densitometry. (2003) p4
Bone Densitometry Course, Clinician Track Syllabus version 5.3 ..... 27, 40, 41, 42, 43, 55

Jakes, R. W. , Khaw, K. , Day, N. E. , Bingham, S. , Welch, A. , Oakes, S. , Luben, R. , Dalzell, N. , Reeve, J. & Wareham, N. (2001).
Patterns of physical activity and ultrasound attenuation by heel bone among Norfolk cohort of European prospective investigation of cancer (EPIC Norfolk): population based study.
British Medical Journal 322 (7279): 140-144. 77

Jones, G. , Riley, M. D. & Dwyer, T. (2000)
Maternal Diet During Pregnancy is Associated with Bone Mineral Density in Childen: a longitudinal study.
European Journal of Clinical Nutrition 54 (10): 749. 53

Jorgensen, N. R. , Henriksen, Z. , Sorensen, O. H. , Eriksen, E. F. , Civitelli, R. & Steinberg, T. H. (2002)
Intercellular Calcium Signalling Occurs Between Human Osteoblasts and Osteoclasts and Requires Activation of Osteoclast P2X7 Receptors.
Journal of Biology and Chemistry 277 (9): 7574-7580. 58

Kanis, J. A. and Gluer, C. C. for the Committee of Scientific Advisors, International Osteoporosis Foundation (2000).
An update on the diagnosis and assessment of osteoporosis with densitometry.
Osteoporosis International 11: 192-202 ..... 92, 104

Kanis, J.A., Delmas, P., Burckhardt, P., Cooper, C., and Torgerson, D. (1997).
Guidlines for Diagnosis and Management of Osteoporosis.
Osteoporosis International 1997 (7): 390-406. ..... 42, 43, 56

Karlsson, M. K. , Duann, Y. , Ahlborg, H. , Obrant, K. J. , Johnell, O. & Seeman, E.
Age, gender, and fragility fractures are associated with differences in quantitative ultrasound independent of bone mineral density.
Bone 28 (1): 118-122. 100

Knapp, K. M. , Andrew, T. , MacGregor, A. J. , Blake, G. M. , Fogelman, I. and Spector, T. D. (2003).
An investigation of unique and shared gene effects on speed of sound and bone density using axial transmission quantitative ultrasound and DXA in twins.
Journal of Bone Mineral Research 18 (8): 1525-1530. 59

Korpelainen, R. , Korpelainen, J. , Heikkinen, J. , Vaananen, K. and Keinanen-Kiukaanniemi, S. (2003)
Lifestyle factors are associated with osteoporosis in lean women but not in normal and overweight women: a population-based cohort study of 1222 women.
Osteoporosis International 14:34-43 72

Lekamwasam, S. , Trivedi, D. P. & Khaw, K. T. (2002).
Osteoporosis International 13 (9): 710-715. 45

Leslie, M. and St. Pierre, R. W. (1999).
Osteoporosis: Implications for risk reduction in the college setting.
Journal of American College Health 48 (2): 67-72 63

Liberman, U. R. , Weiss, S. R. , Broll, J. *et al* (1995)
Effect of Oral Alendronate on Bone Mineral Density and the Incidence of Fractures in Post Menopausal Osteoporosis.
New England Journal of Medicine; 333:1437-1443 56

Lloyd, T. , Chinchilli, V.M. , Johnson-Rollings, N. , Kieselhorst, K. , Eggli, D.F. and Marcus, R. (2000)
Adult Female Hip Bone Density Reflects Teenage Sports - Exercise Patterns But Not Teenage Calcium Intake.

Paediatrics 106 (1): 40-46. 78
Looker, A.C. , Wahner, H. W. , Dunn, W. L. , *et al* (1998).
Up-dated data on proximal femur bone mineral levels of US adults.
Osteoporosis International (8); 468-489. 106
Lypaczewski, G. , Lappe, J. and Stubby, J. (2002).
"Mom & me" and healthy bones: An innovative approach to teaching bone health.
Orthopaedic Nursing 21 (2): 35-42. 62
Maalouf, G. , Salem, S. , Sandid, M. , Attallah, P. Eid, J. , Saliba, N. , Nehme, I. & Johnell, O. (2000).
Bone mineral density of the Lebanese reference population.
Osteoporosis International 11 (9): 756-764. 212
Mackelvie, K. J. , Mckay, H.A. , Khan, K. M. & Crocker, P. R. E. (2001).
Lifestyle risk factors for osteoporosis in Asian and Caucasian girls.
Medicine & Science in Sports & Exercise 33 (11): 1818-1824 ..... 74, 119
Magkos, F. , Manios, Y. , Babaroutsi, E. and Sidossis, L. S. (2005)
Quantitative Ultrasound Calcaneus Measurements: Normative Data for the Greek Population.
Osteoporosis International 16(3):280-288 ..... 226, 227
Marshall, D. , Johnell, O. and Wedel, H. (1996).
Meta-analysis of how well measures of bone mineral density predict occurance of osteoporotic fractures.
British Medical Journal 312: 1254-1259. 104
Mathew, J.
UAE: A Meed Practical & Business Guide, 5th Ed.
(London: Emap Business International) 22, 51, 53
McGuigan, F. E. , Murray, L. , Gallagher, A. , Davey-Smith, G. , Neville, C. E. Van't Hof, R. , Boreham, C. & Ralston, S. H. (2002).
Genetic and environmental determinants of peak bone mass in young men and women.
Journal of Bone Mineral Research 17 (7): 1273-1279. 59
Melton, L. J. III (1995)
How many women have osteoporosis now?
J Bone Miner Res:10(2):175-177. 42
Melton, L. J. III (1996)
Epidemiology of hip fractures: implications of the exponential increase with age.
Bone 18: 121-125. 42
Meunier, P. J. , Sebert, J. L. , Reginster, J. Y. , Briancon, D. , Appelboom, T. et al (1998)
Fluoride Salts are no Better at Preventing New Vertebral Fractures than Calcium-Vitamin D in Postmenopausal Osteoporosis: the FAVO Study.
Osteoporosis International 8 (1):4-12. 56
Middle East Health. (2000)
Groundbreaking accreditation received by Dubai Hospital.
Middle East Health 2000 (November): 8 ..... 52, 58, 60
Million Women Study Collaborators, (2003).
Breast Cancer and Hormone Replacement Therapy in the Million Women Study. Lancet 362:419-427.48
Ministry of Planning (2003)
Federal Government, UAE
Available online 49
Muslim, N. (2005)
Heart Disease Mortality Rate Could Rise
Gulf News: 23 Sep 2005, p6 79
Mussolini, M. E. , Looker, A. C. & Orwoll, E. S. (2001).
Jogging and bone mineral density in men: Results from NHANES III.
American Journal of Public Health 91 (7): 1056-1059 ..... 74, 77, 119
National Admissions and Placement Office
Ministry of Higher Education
Available at: http://www.napo.ae/
Accessed on: 16 October 2005 115
National Institute of Health (2001)
Consensus Development Panel
Journal of the American Medical Association : 285-603 28
National Institute of Health: Osteoporosis and Related Bone Diseases~National Resource Center. (1999)
Peak Bone Mass in Women.
(NIH ORBD~NRC)
Available at: http://www.osteo.org/docs/199.464648147.html

Accessed on 24 October 2001 23
National Institute of Health: Osteoporosis and Related Bone Diseases~National Resource Center. (2000)
Fast Facts on Osteoporosis.
(NIH ORBD~NRC)
Available at: http://www.osteo.org/docs/184.464648147.html
Accessed on 24 October 2001 ..... 40, 43
National Institute of Health: Osteoporosis and Related Bone Diseases~National Resource Center. (2000)
Osteoporosis Overview.
(NIH ORBD~NRC)
Available at: http://www.osteo.org/docs/60.464648147.html
Accessed on 24 October 2001 73
National Osteoporosis Foundation. (2000)
Physician's Guide to Prevention and Treatment of Osteoporosis.
(Washington: NOF)
Available at: http://www.nof.org/_vti_bin/shtml.dll/physguide/index.htm 43, 65, 71, 74, 83, 102
Neer, R. M. , Arnaud, C. D. , Zanchetta, J. R. *et al* (2001)
Effect of Parathyroid Hormone (1-34) on Fractures and Bone Mineral Density in Postmenopausal Women with Osteoporosis.
New England Journal Medicine (344) : 1434-1331 57
Nicholsen, P. H. , Bouxsien, M. L. (2002)
Effect of Temperature on Ultrasonic Properties of the Calcaneus in Situ.
Osteoporosis International 13 (11):888-892. 88
Nieswiadomy, R. M. (2002).
Foundations of nursing research: 4th edition.
(USA: Prentice Hall). 115, 118, 120
Oral, A. , Yaliman, A. and Sindel, D. (2004)
Differences between the right and the left foot in calcaneal quantitative ultrasound measurements.
European Radiology 14(8):1427-1431. 226
Ortolani, S. & Vai, S. (2006)
Strontium Ranelate: An Increased Bone Quality Leading to Vertebral Antifracture Efficacy at all Stages.
Bone 38:19-22. 57
Osteoporosis Society of Canada. (2001)
Osteoporosis Online: Prevention.
(The Osteoporosis Society of Canada)
Available at: http://www.osteoporosis.ca/OSTEO/D02-01c.html
Accessed on 19 August 2001 ..... 36, 74
Ott, S. (2006)
Osteoporosis and Bone Physiology.
(Department of Medicine, University of Washington)
Available at: http://www.courses.washington.edu/bonephys/ophome.html
Accessed on 26 May 2006 ..... 32, 48, 49, 75
Pagano, M. and Gauvreau, K. (2000).
Principles of Biostatistics: 2nd edition.
(USA: Duxbury) 114, 119, 120, 150
Peterson, B. A. , Klesges, R. C. , Kaufman, E. M. , Cooper, T. V. & Vukadinovich, C. M. (2000).
The effects of an educational intervention on calcium intake and bone mineral content in young women with low calcium intake.
American Journal of Health Promotion 14 (3): 149-156. 63
Pinto, B. M. & Cherico, N. P. (1998)
Longitudinal changes in college students' exercise participation.
Journal of American College Health 47 (1): 23-28 78
Reginster, J. Y. , Felsenburg, D. , Pavo, I. , Stepan, J. Payer, J. et al (2003)
Effect of Raloxifene Combined with Monofluorophosphate as Compared with Monofluorophosphate Alone in Postmenopausal Women with Low Bone Mass: a Randomized, Controlled Trial.
Osteoporosis International 14 (9):741-749. 56
Reginster, J. Y. , Meurmans, L. , Zegels, B. , Rovati, L. C. , Minne, H. W. *et al* (1998)
The Effect of Sodium Monofluorophosphate Plus Calcium on Vertebral Fracture Rate in Postmenopausal Women with Moderate Osteoporosis. A Randomized, controlled Trial.
Annals of Internal Medicine 129 (1):1-8. 56
Research and Studies Department, Dubai Chamber of Commerce and Industry, 2000
Available online 49

End Matters

Riggs, B. L. , Hodgson, S. F. , O'Fallon, W. M. , et al (1990)
Effect of Fluoride Treatment on the Fracture Rate in Postmenopausal Women.
New England Journal of Medicine 322:802-809. 56
Riggs, B. L. , Melton, L. J. , Robb, R. A. , Camp, J. J. , Atkinson, E. J. et al (2004)
Population-Based Study of Age and Sex Differences in Bone Volumetric Density, Size, Geometry, and Structure at Different Skeletal Sites.
Journal of Bone and Mineral Research 19 (12):1945-1954. 189
Riggs, B.L. , Melton, L.J. (1992)
The Prevention and Treatment of Osteoporosis.
New England Journal of Medicine 1992 (327): 620-627. 78
Ringe, J. D. , Dorst, A. , Faber, H. , Kipshoven, C. , Rovat, L. C. & Setnikar, I. (2005)
Efficacy of Etidronate and Sequential Monofluorophosphate in Severe Postmenopausal Osteoporosis: a pilot study.
Rheumatology International 25 (4):296-300. 56
Röben, P. , Barkmann, R. , Ullrich,S. , Gause, A. , Heller, M. and Gluer, C-C (2001)
Assessment of Phalangeal Bone Loss in Patients with Rheumatoid Arthritis by Quantitative Ultrasound
Annals of Rheumatic Disease (60):670-677 89
Royal College of Physicians (2000).
Osteoporosis: clinical guidlines for prevention and treatment. Update on pharmacological interventions and an algorithm for treatment.
(London: RCP). 104
Saadi, H. F. , Reed, R,. L. , Carter, A. O. & Al Suhaili, A. R. (2004).
Correlation of quantitative ultrasound parameters of the calcaneus with bone density of the spine and hip in women with prevalent hypovitaminosis D.
Journal of Clinical Densitometry 7 (3): 313-318. ..... 24, 69
Saadi, H. F. , Reed, R. L. , Carter, A. O. , Dunn, E. V. , Qazaq, H. S. & Al Suhaili, A. R. (2003).
Quantitative ultrasound of the calcaneus in arabian women: relation to anthropometric and lifestyle factors.
Maturitas 44: 215-223. ..... 24, 68, 131, 212
Saadi, H.F. , Reed, R. L. , ,Carter, A. O. , Qazaq, H. S. and Suhaili, A. R. (2001).
Bone density estimates and risk factors for osteoporosis in young women.
Eastern Mediterranean Health Journal 7 (4/5): 730-737 ..... 24, 37, 67, 73
Sasche, A. , Wagner, A. , Keller, M. , *et al* (2005)
Osteointegration of Hydroxyapatite-Titanium Implants Coated with Nonglycosylated Recombinant Human Bone Morphogenetic Protein-2 (BMP-2) in Aged Sheep.
Bone Aug 2005 Elsevier Epub. 58
Shih, T. T. , Liu, H. C. , Chang, C. J. , Wei, S. Y. , Shen, L. C. & Yang, P. C. (2004).
Correlations of MR lumbar spine bone marrow perfusion with bone mineral density in female subjects.
Radiology 233 (1): 121-128. 107
Shilbayeh, S. (2003).
Prevalence of osteoporosis and its reproductive risk factors among Jordanian women: a cross-sectional study.
Osteoporosis International 14 (11): 929-940. ..... 37, 70
Shin, M. H. , Kweon, S. S. , Park, K. S. , Heo, H. , Kim, S. J. et al (2005)
Quantitative Ultrasound of the Calcaneus in a Korean Population: Reference Data and Relationship to Bone Mineral Density Determined by Peripheral Dual X-ray Absorptiometry.
Journal Korean Medical Science 20:1011-1016. 227
Simon, L.S. (1998)
Osteoporosis: Etiology and Pathogenesis.
Rheumatology & Musculoskeletal Medicine for primary care 1 (2): 5-14. ..... 34, 37, 40
Siris, S. S. , Miller, P.D. , Barrett-Connor, E. , Faulkner, K. G. , Wehren, L. E. , Abbott, T. A. , Berger, M. L. , Santora, A.C. & Sherwood, L. M. (2001)
Identification and fracture outcomes of undiagnosed low bone mineral density in postmenopausal women.
Journal of American Medical Association 286: 2815-2822 105
Soanes, C and Stevenson, A. (2004)
Concise Oxford English Dictionary, 11th Ed.
(Oxford: University Press) 21
Solgaard, M. & Jorgensen, N. R. (2005)
P2 Purinergic Receptors: Regulation of Bone Metabolism and Therapeutic Potential?
Ugeskr Laeger 167(34): 3152-3156. 58
South, J. (2001)
Osteoporosis: Part I. Evaluation and assessment.
American Family Physician 63: 897-904, 908 91

End Matters

Steiger, P. , Block, J. E. , Steiger, S. , Heuck, A. , Friedlander, A. , Ettinger, B. , Harris, S. T. , Gleur, C. C. , Genant, H. K. (1990)
Spinal bone mineral densityby quantitative computed tomography: Effect of region of interest, vertebral level, and technique.
Radiology 175: 537-543 99
Stepan, J. J. , Lachman, M. , Zverina, J. *et al* (1989).
Castrated men exhibit bone loss: effect of calcitonin treatment on biochemical indices of bone remodelling.
Journal of Clinical Endocrinology Metabolism. 70
Stolz, C. and Squires, S. (2002)
'A' bone of contention.
Gulf News Tabloid 16 January 2002: 5. 60
Suhaili, 2005
Head of Nuclear Medicine, Dubai Hospital, Dubai, UAE
Personal Communication 61
Suhaili, A (2004)
Personal Communication
Chief Nuclear Medicine Physician, Tawam Hospital, Al Ain, UAE 20
Taxel, P. (1998)
Osteoporosis: Detection, Prevention, and Treatment in Primary Care.
Geriatrics 53 (8): 22-30. 42
Teach Nutrition
Available at:
http://www.teachnutrition.org/ie/calculator/NN3_5.htm
Accessed on: 13 Sept 2003 133
Todd, J. A. and Robinson, R. J. (2003).
Osteoporosis and exercise.
Postgraduate Medical Journal 79: 320-323. 76
Tonini, R. P. , Meunier, P. J. , Emkey, R. *et al* (2000)
Skeletal Benefits of Alendronate: 7 Year Treatment of Postmenopausal Osteoporotic Women. Phase III Osteoporosis Treatment Study Group.
Journal of Clinical Endocrinology Metabolism; 85:3109-3115 56
Tortora, G. J. and Grabowski, S. R. (2000) p163
Principles of Anatomy and Physiology 9th Ed.
(New York:Wiley). 30, 31, 33, 35
Tuck, S. P. & Francis, R. M. (2002).
Osteoporosis.
Postgraduate Medical Journal 78: 526-532. ..... 71, 77
van der Meulen, M. C. H. , Moro, M. , Kiratli, B.J. , Marcus, R. and Bachrach, L. K. (2000).
Mechanobiology of femoral neck structure during adolescence.
Journal of Rehabilitation Research and Development 37 (2): 201-208. 72
Villaca, J. H. , Novaes, A. B. Jr, Souza, S. L. , Taba, M. Jr , Molina, G. O. & Carvalho, T. L. (2005)
Bioactive Glass Efficacy in the Peridontal Healing of Intrabony Defects in Monkeys.
Brazilian Dental Journal 16 (1): 67-74. 58
Weaver, C. M. , Teegarden, D. , Lyle, R. M. , McCabe, G. P. , McCabe, L. D. , Proulx, W. , Kern, M. , Sedlock, D. , Anderson, D. D. , Hillberry, B. M. , Peacock, M. & Conrad, J. C. (2003).
Impact of exercise on bone health and contraindication of oral contraceptive use in young women.
Medicine & Science in Sports & Exercise 33 (6): 873-880 77
Wekslar, M. E. (1997).
New Frontiers: Osteoporosis.
Geriatrics 52 (4): 92-97. 43
Westbrook, C. , Kaut, C. (1998)
MRI in Practice.
Oxford: Blackwell Science. 112
WHO, (1994)
WHO Technical Report Series
Geneva: WHO 29, 102
Woolf, A. D. (1999).
Bulletin of the WHO: Strong Bones in Later Life.
(WHO/OMS)
Available at: http://www.who.int/bulletin/editorials/issue5/strongbones
Accessed on 15 January 2002 ..... 29, 30

End Matters

Woolf, A. D. , Pfleger, B, (2003)
Burden of Major Musculoskeletal Conditions
Bulletin of the world health organization 81(9):646-656 28
World Health Organization. (2001)
Behavioural Risk Factor Surveillance.
(WHO/OMS)
Available at: http://www.who.int/hpr/brfs/brfsindex.htm
Accessed on 7 March 2001 ..... 29, 51
Wyshak, G. (2000).
Teenage girls, carbonated beverage consumption, and bone fractures.
Archives Paediatric Adolescent Medicine 154: 610-613 75
Yeung, D. K. , Wong, S. Y. , Griffith, J. F. & Lau, E. M. (2004).
Journal Magnetic Resonance Imaging 19 (2): 222-228. 106

APPENDICES

APPENDIX A –Methodological and Ethical Approval

University of Sharjah
College of Health Sciences
Dean's Office

جـامـعـة الشـارقـــة
كلية العلوم الصحية
مكتب العميد

January 11, 2005 Ref: DO / 05 / 48

Ms Penelope Jane Bell
Lecturer
Dept. of Medical Diagnostic Imaging
College of Health Sciences
University of Sharjah

Dear Ms Bell,

I have the pleasure to inform you that members of the College of Health Sciences - Institutional Review Board (IRB) at the University of Sharjah have carefully reviewed your submitted proposal entitled: "***Estimated Bone Mineral Density, Diet and Exercise in Students at the University of Sharjah, UAE***".

Accordingly, the IRB members are pleased to grant you approval of the ethical principals and methodological framework involved in this submission.

The committee recommends that you consult a biostatistician to assist the research team in planning and implementing data analysis and interpretation of the study findings.

The members of the committee wish you all the success in your research and other future endeavors

Sincerely,

Ahmed Mandil, MBChB, Dr.PH
Prof. & Chair
CHS Institutional Review Board

Cc: Dr. Manal Awad, Secretary, IRB

ص.ب : ٢٧٢٧٢، الشارقة – الإمارات العربية المتحدة – هاتف : ٥٠٥٠٨٠١ (٩٧١٦) – فاكس : ٥٠٥٠٨٠٢ (٩٧١٦)
P.O. Box : 27272, Sharjah - United Arab Emirates - Tel : (9716) 5050801 - Fax : (9716) 5050802

Higher Colleges of Technology
Dubai Women's College
DWC Research Committee

November 27, 2004

Penelope Bell
University of Sharjah

Dear Penelope,

Thank you for your application. Many apologies for the delay as the mourning period put quite a twist into our schedule.

After reviewing your research plans, the information and consent letters the DWC Research Committee has approved your application for the research.

Your research sounds very worthy and we wish you the best of luck.

Yours sincerely,

Cheri MacLeod

Chairperson
DWC Research Committee
Dubai Women's College

Cheri MacLeod
Dubai Women's College

APPENDIX B – MOH Permission Letter

UNITED ARAB EMIRATES

MINISTRY OF HEALTH

دولة الامارات العربية المتحدة

وزارة الصحـــة

ORIGIN :

Ref. :

Date : 30 April, 2005

المصـــدر .....

الرقـــم .....

التاريـخ ... / ... / ١٤ هـ

الموافـق ... / ... / ٢٠٠ م

Professor Ahmed Mandil
Dean of College of Health Sciences
University of Sharjah

Dear Dr Ahmed Mandil

In response to your letter regarding the research project "Bone Mineral Density, lifestyle, Diet and Exercise in UAE Students", the Sharjah Medical District has reviewed the request for a limited number of Universtiy of Sharjah Students to be allowed to attend the Medical Diagnostic Imaging Department in New Al Qassimi Hospital for MRI scanning.

As you mentioned in your letter, this research project has been approved by the University Research Board and gets full methodological and ethical approval from the College of Health Sciences Institutional Review Board.

It is understood that the students will require an MRI scan of their heel as part of this research project conducted by Ms. Penelope Bell, lecturer in Medical Diagnostic Imaging Department, College of Health Sciences, who is investigating bone density, diet, exercise and life style.

The Sharjah Medical District has no objection to this request provided that the MRI scan timings are co-ordinated with Dr. Hatem Abou El Abbass, Head of the Radiology Department, and do not disrupt the daily operation of the department. Please note that the usual fee for each MRI scan will be charged which is 500 Dirhams per study. A maximum of 20 students could be accommodated.

Yours Sincerely,

Sheikh Mohammed Bin Saqr Al Qassimi
Assistant Under Secretary, MOH
Director of Sharjah Medical District

Sharjah P.O. Box : 2072 Tel. 5631117, Fax: 5635456, United Arab Emirates الشارقة ص.ب ٢٠٧٢ تلفون ٥٦٣١١١٧، فاكس ٥٦٣٥٤٥٦، الامارات العربية المتحدة

M. H. 3

APPENDIX C – Anova Tests – Bone Strength to Age

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
QUS lowest heel	18	17	101	20	5	91	112	62	135
	19	21	101	15	3	94	108	75	135
	20	24	97	11	2	92	102	77	120
	21	14	94	11	3	88	101	72	108
	22	10	87	14	5	77	98	69	118
	23	14	93	14	4	85	101	72	117
	24	10	102	19	6	88	116	75	131
	25	2	85	2	2	65	104	83	86
	Total	112	97	15	1	94	100	62	135
Right heel stiffness index	18	17	107	23	6	95	119	62	159
	19	21	104	17	4	96	112	75	153
	20	24	101	14	3	95	107	77	134
	21	14	97	11	3	90	103	75	111
	22	10	92	19	6	78	105	69	129
	23	14	95	15	4	87	104	72	117
	24	10	110	24	8	93	128	77	152
	25	2	87	1	1	80	93	86	87
	Total	112	101	18	2	98	104	62	159
Left heel stiffness index	18	17	106	19	5	96	116	72	135
	19	21	104	18	4	96	112	76	136
	20	23	100	11	2	95	105	80	123
	21	14	95	12	3	89	102	72	114
	22	10	93	12	4	84	101	79	118
	23	14	98	17	5	88	108	72	125
	24	10	104	21	7	89	119	75	131
	25	2	85	2	2	65	104	83	86
	Total	111	100	16	2	97	103	72	136
Average QUS value	18	17	106	20	5	96	117	69	147
	19	21	104	17	4	96	112	76	144
	20	23	101	12	2	96	106	79	125
	21	14	96	11	3	89	102	74	111
	22	10	92	14	5	82	102	76	124
	23	14	97	15	4	88	105	72	120
	24	10	107	22	7	91	123	76	142
	25	2	86	1	1	79	92	85	86
	Total	111	101	16	2	98	104	69	147
DXA g/cm2 Total hip	18	2	1.039	.172	.122	-.505	2.582	.917	1.160
	19	7	1.039	.124	.047	.925	1.154	.891	1.259
	20	6	1.036	.085	.035	.947	1.126	.904	1.134
	21	1	1.099	.	.	.	.	1.099	1.099
	22	3	1.094	.155	.089	.709	1.479	.915	1.192
	23	5	.924	.118	.053	.778	1.070	.774	1.094
	24	6	1.117	.142	.058	.968	1.266	.907	1.277
	25	1	.884	.	.	.	.	.884	.884
	Total	31	1.037	.129	.023	.990	1.085	.774	1.277
DXA g/cm2 neck	18	2	.930	.072	.051	.282	1.578	.879	.981
	19	7	.898	.082	.031	.823	.973	.803	.994
	20	6	.918	.032	.013	.884	.951	.873	.953
	21	1	1.071	.	.	.	.	1.071	1.071
	22	3	.906	.152	.088	.528	1.284	.733	1.018
	23	5	.836	.133	.059	.671	1.001	.611	.950
	24	6	.917	.127	.052	.784	1.050	.744	1.062
	25	1	.849	.	.	.	.	.849	.849
	Total	31	.902	.101	.018	.865	.939	.611	1.071
DXA g/cm2 trochanter	18	2	.787	.112	.079	-.217	1.791	.708	.866
	19	7	.785	.116	.044	.678	.893	.681	1.001
	20	6	.775	.071	.029	.700	.849	.649	.843
	21	1	.856	.	.	.	.	.856	.856
	22	3	.807	.101	.058	.557	1.057	.704	.905
	23	5	.681	.078	.035	.584	.777	.573	.766
	24	6	.849	.127	.052	.716	.982	.697	1.043
	25	1	.680	.	.	.	.	.680	.680
	Total	31	.780	.106	.019	.741	.819	.573	1.043
DXA g/cm2 intertroch	18	2	1.226	.268	.190	-1.182	3.633	1.036	1.415
	19	7	1.231	.152	.057	1.091	1.372	1.049	1.505
	20	6	1.239	.142	.058	1.090	1.388	1.052	1.402
	21	1	1.264	.	.	.	.	1.264	1.264
	22	3	1.302	.178	.103	.861	1.743	1.097	1.412
	23	5	1.086	.152	.068	.897	1.275	.921	1.319
	24	6	1.348	.173	.071	1.166	1.529	1.076	1.513
	25	1	1.021	.	.	.	.	1.021	1.021
	Total	31	1.233	.170	.030	1.170	1.295	.921	1.513

[a] Volunteer source = UOS males

Means of bone strength by age, males

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
QUS lowest heel	Between Groups	2501.693	7	357.385	1.584	.148
	Within Groups	23469.414	104	225.667		
	Total	25971.107	111			
Right heel stiffness index	Between Groups	3595.900	7	513.700	1.647	.131
	Within Groups	32444.350	104	311.965		
	Total	36040.250	111			
Left heel stiffness index	Between Groups	2463.152	7	351.879	1.404	.212
	Within Groups	25811.173	103	250.594		
	Total	28274.324	110			
Average QUS value	Between Groups	2916.998	7	416.714	1.621	.138
	Within Groups	26473.236	103	257.022		
	Total	29390.234	110			
DXA g/cm2 Total hip	Between Groups	.139	7	.020	1.260	.313
	Within Groups	.361	23	.016		
	Total	.500	30			
DXA g/cm2 neck	Between Groups	.058	7	.008	.767	.620
	Within Groups	.248	23	.011		
	Total	.305	30			
DXA g/cm2 trochanter	Between Groups	.097	7	.014	1.301	.294
	Within Groups	.244	23	.011		
	Total	.340	30			
DXA g/cm2 intertroch	Between Groups	.247	7	.035	1.318	.286
	Within Groups	.616	23	.027		
	Total	.863	30			

a. Volunteer source = UOS males

Anova of bone strength by age, males

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
QUS lowest heel	18	20	93	11	2	88	99	75	118
	19	26	94	13	2	88	99	70	115
	20	28	88	11	2	84	92	66	114
	21	30	90	13	2	85	95	73	122
	22	8	88	8	3	82	95	73	97
	23	7	96	11	4	86	106	86	111
	24	0	.	.	.	.	.	.	.
	25	1	90	.	.	.	.	90	90
	Total	120	91	12	1	89	93	66	122
Right heel stiffness index	18	20	96	13	3	90	102	80	127
	19	26	96	14	3	90	102	70	129
	20	27	91	12	2	86	96	73	116
	21	30	94	14	3	89	99	73	122
	22	8	90	9	3	83	98	73	99
	23	7	102	18	7	86	119	88	135
	24	0	.	.	.	.	.	.	.
	25	1	90	.	.	.	.	90	90
	Total	119	94	13	1	92	97	70	135
Left heel stiffness index	18	20	97	12	3	91	103	75	124
	19	26	96	13	2	91	101	73	115
	20	27	92	12	2	87	97	66	114
	21	30	94	16	3	88	99	75	131
	22	8	89	6	2	84	94	80	97
	23	7	97	12	4	87	108	85	111
	24	0	.	.	.	.	.	.	.
	25	1	93	.	.	.	.	93	93
	Total	119	94	13	1	92	97	66	131
Average QUS value	18	20	97	12	3	91	102	78	121
	19	26	96	13	3	91	101	74	122
	20	27	92	11	2	87	96	70	115
	21	30	94	14	2	89	99	74	124
	22	8	90	7	3	84	96	77	98
	23	7	100	14	5	87	113	88	123
	24	0	.	.	.	.	.	.	.
	25	1	92	.	.	.	.	92	92
	Total	119	94	12	1	92	97	70	124
DXA g/cm2 Total hip	18	9	.892	.157	.052	.771	1.012	.663	1.101
	19	8	.815	.109	.039	.724	.907	.662	.939
	20	12	.813	.102	.029	.749	.878	.682	1.021
	21	7	.823	.101	.038	.730	.917	.682	.992
	22	0	.	.	.	.	.	.	.
	23	2	.734	.016	.011	.594	.874	.723	.745
	24	0	.	.	.	.	.	.	.
	25	0	.	.	.	.	.	.	.
	Total	38	.830	.118	.019	.791	.869	.662	1.101
DXA g/cm2 neck	18	9	.776	.144	.048	.666	.887	.599	.965
	19	8	.743	.119	.042	.644	.843	.585	.839
	20	12	.709	.101	.029	.644	.773	.563	.925
	21	7	.712	.075	.028	.643	.781	.604	.820
	22	0	.	.	.	.	.	.	.
	23	2	.599	.001	.001	.586	.612	.598	.600
	24	0	.	.	.	.	.	.	.
	25	0	.	.	.	.	.	.	.
	Total	38	.727	.113	.018	.690	.764	.563	.965
DXA g/cm2 trochanter	18	9	.665	.123	.041	.571	.760	.480	.834
	19	8	.604	.096	.034	.523	.684	.469	.760
	20	12	.614	.102	.030	.549	.679	.441	.777
	21	7	.632	.134	.051	.508	.755	.474	.854
	22	0	.	.	.	.	.	.	.
	23	2	.526	.013	.009	.412	.640	.517	.535
	24	0	.	.	.	.	.	.	.
	25	0	.	.	.	.	.	.	.
	Total	38	.622	.110	.018	.586	.659	.441	.854
DXA g/cm2 intertroch	18	9	1.071	.178	.059	.935	1.208	.814	1.307
	19	8	.960	.121	.043	.859	1.062	.776	1.088
	20	12	.966	.108	.031	.897	1.035	.796	1.166
	21	7	.993	.128	.048	.875	1.112	.802	1.209
	22	0	.	.	.	.	.	.	.
	23	2	.908	.008	.006	.838	.977	.902	.913
	24	0	.	.	.	.	.	.	.
	25	0	.	.	.	.	.	.	.
	Total	38	.992	.135	.022	.948	1.036	.776	1.307

a. Volunteer source = UOS females

Means of bone strength by age, UOS females

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
QUS lowest heel	Between Groups	775.886	6	129.314	.954	.460
	Within Groups	15317.239	113	135.551		
	Total	16093.125	119			
Right heel stiffness index	Between Groups	1002.030	6	167.005	.942	.468
	Within Groups	19847.382	112	177.209		
	Total	20849.412	118			
Left heel stiffness index	Between Groups	652.694	6	108.782	.637	.701
	Within Groups	19133.155	112	170.832		
	Total	19785.849	118			
Average QUS value	Between Groups	763.135	6	127.189	.824	.554
	Within Groups	17287.798	112	154.355		
	Total	18050.933	118			
DXA g/cm2 Total hip	Between Groups	.058	4	.015	1.049	.397
	Within Groups	.457	33	.014		
	Total	.515	37			
DXA g/cm2 neck	Between Groups	.062	4	.016	1.248	.310
	Within Groups	.412	33	.012		
	Total	.475	37			
DXA g/cm2 trochanter	Between Groups	.040	4	.010	.801	.533
	Within Groups	.408	33	.012		
	Total	.448	37			
DXA g/cm2 intertroch	Between Groups	.087	4	.022	1.225	.319
	Within Groups	.583	33	.018		
	Total	.670	37			

a. Volunteer source = UOS females

Anova of bone strength by age, UOS females

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
QUS lowest heel	18	5	98	10	5	85	111	88	115
	19	8	91	13	5	80	102	75	108
	20	8	97	17	6	83	111	76	118
	21	7	92	12	4	81	102	75	106
	22	2	86	10	7	-3	175	79	93
	23	2	84	28	20	-170	338	64	104
	24	1	92	.	.	.	.	92	92
	Total	33	93	14	2	88	98	64	118
Right heel stiffness index	18	4	102	10	5	85	118	94	117
	19	8	99	20	7	82	116	75	137
	20	8	105	20	7	88	121	76	129
	21	7	94	11	4	83	104	75	107
	22	2	94	9	7	11	176	87	100
	23	2	86	26	19	-150	321	67	104
	24	1	111	.	.	.	.	111	111
	Total	32	99	17	3	93	105	67	137
Left heel stiffness index	18	5	101	12	5	86	116	88	115
	19	8	92	15	5	80	104	77	114
	20	8	98	15	5	85	111	83	118
	21	7	94	13	5	82	106	75	114
	22	2	86	10	7	-3	175	79	93
	23	2	87	32	23	-199	372	64	109
	24	1	92	.	.	.	.	92	92
	Total	33	95	14	2	89	100	64	118
Average QUS value	18	4	102	11	6	84	120	91	116
	19	8	95	17	6	81	110	76	123
	20	8	101	17	6	87	116	80	123
	21	7	94	12	5	83	105	75	110
	22	2	90	10	7	4	176	83	97
	23	2	86	29	21	-174	346	66	107
	24	1	102	.	.	.	.	102	102
	Total	32	97	15	3	91	102	66	123

a. Volunteer source = DWC females

Means of bone strength by age, DWC females

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
QUS lowest heel	Between Groups	572.653	6	95.442	.468	.825
	Within Groups	5299.589	26	203.830		
	Total	5872.242	32			
Right heel stiffness index	Between Groups	1038.286	6	173.048	.571	.749
	Within Groups	7573.214	25	302.929		
	Total	8611.500	31			
Left heel stiffness index	Between Groups	622.007	6	103.668	.456	.834
	Within Groups	5906.175	26	227.161		
	Total	6528.182	32			
Average QUS value	Between Groups	687.853	6	114.642	.457	.833
	Within Groups	6268.522	25	250.741		
	Total	6956.375	31			

a. Volunteer source = DWC females

Anova of bone strength by age, DWC females

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
QUS lowest heel	18	25	94	11	2	90	99	75	118
	19	34	93	13	2	88	97	70	115
	20	36	90	13	2	86	95	66	118
	21	37	90	12	2	86	94	73	122
	22	10	88	8	2	82	93	73	97
	23	9	94	15	5	82	105	64	111
	24	1	92	.	.	.	.	92	92
	25	1	90	.	.	.	.	90	90
	Total	153	91	12	1	90	93	64	122
Right heel stiffness index	18	24	97	12	3	92	102	80	127
	19	34	96	16	3	91	102	70	137
	20	35	94	15	3	89	99	73	129
	21	37	94	13	2	90	98	73	122
	22	10	91	8	3	85	97	73	100
	23	9	99	20	7	84	114	67	135
	24	1	111	.	.	.	.	111	111
	25	1	90	.	.	.	.	90	90
	Total	151	95	14	1	93	97	67	137
Left heel T score	18	25	0	1	0	-1	0	-2	2
	19	34	0	1	0	-1	0	-2	1
	20	35	-1	1	0	-1	0	-3	1
	21	37	0	1	0	-1	0	-2	2
	22	10	-1	0	0	-1	-1	-2	0
	23	9	0	1	0	-1	1	-3	1
	24	1	-1	.	.	.	.	-1	-1
	25	1	-1	.	.	.	.	-1	-1
	Total	152	0	1	0	-1	0	-3	2
Average QUS value	18	24	97	12	2	92	102	78	121
	19	34	96	14	2	91	101	74	123
	20	35	94	13	2	89	98	70	123
	21	37	94	13	2	89	98	74	124
	22	10	90	7	2	85	95	77	98
	23	9	97	17	6	84	110	66	123
	24	1	102	.	.	.	.	102	102
	25	1	92	.	.	.	.	92	92
	Total	151	95	13	1	93	97	66	124

a. Sex = Female

Means of bone strength by age, all females

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
QUS lowest heel	Between Groups	557.324	7	79.618	.537	.805
	Within Groups	21484.924	145	148.172		
	Total	22042.248	152			
Right heel stiffness index	Between Groups	783.781	7	111.969	.549	.796
	Within Groups	29163.080	143	203.938		
	Total	29946.861	150			
Left heel T score	Between Groups	4.465	7	.638	.608	.748
	Within Groups	150.960	144	1.048		
	Total	155.425	151			
Average QUS value	Between Groups	615.622	7	87.946	.513	.824
	Within Groups	24525.811	143	171.509		
	Total	25141.434	150			

a. Sex = Female

Anova of bone strength by age, all females

APPENDIX D – F1 Information Brochure, Side 1 and 2

Facts you should know:

- The research will be conducted by Ms Bell, Lecturer in Medical Diagnostic Imaging, University of Sharjah. She has a degree in Radiography from London, UK. She is also certified in bone density measurement. The research has been funded by a research grant from the University of Sharjah Research Board. Contact details are given here.
- All information will be confidential. Each participant will be identified during the research by a code number only. No names or codes will be used in the final report.
- Any student is welcome to volunteer for the study by contacting Ms Bell. The student may also refuse to continue and withdraw at any point.
- The results of the study will be available from the University of Sharjah after completion. Individual bone density results will be given to participants.

DXA images for hip and spine.

Osteoporosis, do you want more info?

Try the following websites:

National Osteoporosis Society www.nos.org.uk

www.nof.org

IOF www.osteofound.org

www.nlm.nih.gov/medlineplus/osteoporosis.html

MedlinePlus® Trusted Health Information for You

www.osteoporosis.ca

Organization

UNIVERSITY OF SHARJAH

Research Project Contact

Ms Penelope Bell

Medical Diagnostic Imaging Department
College of Health Sciences
University of Sharjah
United Arab Emirates
Phone Office: +971 6 5050803
Phone Mobile: 050 6545704
Fax: +971 6 5050802
Email: bell@sharjah.ac.ae

UNIVERSITY OF SHARJAH

Research Project: Bone Mineral Density, Diet and Exercise in Students at the University of Sharjah

Normal Bone Osteoporotic Bone
Images courtesy :
International Osteoporosis Foundation

Information Brochure
Please read and volunteer!

Healthy Bones—as strong as possible for as long as possible

As we get older we naturally lose bone, as bones get weaker they can break.

Do you think about your bones? You can't see them or feel them, so how do you know if they are healthy?

Join this research project to find out if you have strong bones and to learn about how to best look after them. A healthy diet and regular exercise are two steps towards strong bones.

Volunteers are needed for this research project which aims to find out about the bone density, diet and lifestyle habits of students at the University of Sharjah. Why are these things important? Because there is a condition called Osteoporosis which is when bones become so weak that they break. This condition usually occurs in women during or after menopause and is very common, 1 in 3 women will be affected. Every persons bones become thinner as they get older BUT if we have a bone friendly lifestyle we can keep our bones as strong as possible for as long as possible.

What will happen if I volunteer?

First you must read this brochure in full. If you have any questions the researcher will try to answer them. If you are happy to become a volunteer you will be asked to sign a form to say that you understand what is required and are prepared to join.

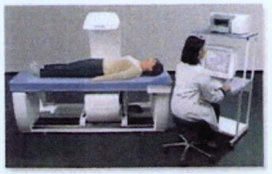
What will I have to do?

You will be asked to fill out a questionnaire which asks about your health and your lifestyle. A further questionnaire will ask about how much physical exercise you do in a week.

Sitting on a chair, your foot rests in this machine. The scan takes only a minute.

Once these forms have been completed, your heel bone will be scanned with an ultrasound machine to estimate your bone density. This procedures uses high frequency sound waves and is quick, safe and painless.

Completing the forms and having a heel scan will take about 15 minutes. You will then need to leave a contact telephone number. The researcher will call you back to arrange for a DXA scan to be done. This type of scan uses a very small amount of xrays to measure the strength of your bones. The World Health Organization (WHO) recommends this type of test as the "Gold Standard" for accurately determining bone density. The ultrasound machine gives us an estimation only. The lower spine and one hip will be scanned. The amount of xrays used is not more than 1 day of normal background radiation which we are all exposed to all the time. The scanner is at Al Baraha Hospital in Dubai. Transport will be arranged for groups of students to go together.



Keeping your clothes on, you lie on a bed for the scans. The two scans will only take a few minutes.

Some students may also be asked to go for a third bone test—Magnetic Resonance Imaging (MRI). This machine does not use xrays. It has a large magnet and uses radiowaves to make a picture. It is safe and painless. This test would be done at Al Qassimi Hospital. Transport would be provided. This scan may take up to 30 minutes, and can be noisy.

APPENDIX E – F2 Consent Form

F2 **Research No _ _ _**

Medical Diagnostic Imaging
College of Health Sciences
University of Sharjah

CONSENT FORM

Research Project:

Bone Mineral Density, Diet and Exercise in Students at the University of Sharjah

Consent to become a volunteer for the above project.

You have been invited to join the above reseach project because you are a healthy young Arab student of 18 years and above studying at the University of Sharjah. You have been given the information brochure F1. After reading it any questions you had have been answered by the researcher. Your participation in this research project will have no effect on your university grades.

All information from this research will remain confidential. You will only be referred to by your research number. A personal information form, containing your name, will be stored in a locked filing cabinet, in a locked office.

Please keep the information brochure with you as it contains contact details. You may contact the researcher, Ms Bell, at any time with questions on mobile 6545704.

I understand that there is a negligble risk to my health from the DXA scan (receiving the equivalent of 1 extra day of background radiation) and that I will benefit from finding out about my bone density.

Your signature on this form means that you have understood what you have been told about the project and that you are volunteering to take part. You may withdraw from the study at any point. You may refuse to participate in any part of the study. The results of the study will be available after completion from the the University of Sharjah.

I _____ _____ _____, Research number _ _ _.

Have read the information brochure and the concent form and agree to participate in the above research project.

_____ ___/___/_____ (DD/MM/YYYY)
signature date

Researcher: P Bell, BSc. (Hons) Applied Radiography, Dip. Radionuclide Imaging, Dip. College Radiographers, Cert. Bone Density ISCD/IOF

P Bell consent form

APPENDIX F – F3 Lifestyle Questionnaire

F3 **Lifestyle Questionnaire**

Q Nr.	Code Choice	Code Result	Q Abbrev

The following questions are about your health, your lifestyle habits and your normal diet. This research project is trying to find out whether University Students have a lifestyle which will keep their bones healthy or not. The questions aim to find out about things which are important to keeping healthy bones such as how much calcium you have in your diet.

Please read the questions carefully and try to answer them as accurately as you can. After you have finished filling in this form, the researcher will go through it with you and try to help if you have any questions.

Date: _____ (dd/mm/yy)

Research No ____

Ref PJB Lifestyle Quest (1) Excel, Pilot 2

F3 **Lifestyle Questionnaire**

Q Nr.	Code Choice	Code Result	Q Abbrev

1.0 About Yourself:

1.1 Age: _____ years [AGE]

Don't Know/Not Sure 0088

Refused 0099

1.2 Date of Birth: _____ (dd/mm/yy) [DOB]

Don't Know/Not Sure 0088

Refused 0099

1.3 Sex: _____ [SEX]

Male 0001

Female 0002

1.4 Ethnic group: _____ [ETH]

Please choose the code from the list below.

Arab 0001

African 0002

Asian 0003

European 0004

1.5 Which major are you studying?

Insert Name of Major _____ [MAJ]

F3 **Lifestyle Questionnaire**

Q Nr.	Code Choice	Code Result	Q Abbrev

1.6 Country of Birth: [COB]

Please choose the code from the list below. If you choose 18 (other) then write the country in the space provided.

UAE	0001
Sudan	0002
Kuwait	0003
Jordan	0004
Egypt	0005
Syria	0006
Lebanon	0007
Qatar	0008
Iran	0009
Saudi	0010
Oman	0011
Turkey	0012
Palestine	0013
Kenya	0014
Morocco	0015
Algeria	0016
America	0017
Other	0018
Specify Other	_____
Don't Know/Not Sure	0088
Refused	0099

F3 **Lifestyle Questionnaire**

Q Nr.	Code Choice	Code Result	Q Abbrev

1.7 **Country lived in the longest:** [DOM]

Please choose the code from the list below. If you choose 18 (other) then write the country in the space provided.

UAE	0001
Sudan	0002
Kuwait	0003
Jordan	0004
Egypt	0005
Syria	0006
Lebanon	0007
Qatar	0008
Iran	0009
Saudi	0010
Oman	0011
Turkey	0012
Palestine	0013
Kenya	0014
Morocco	0015
Algeria	0016
America	0017
Other	0018
Specify Other	_____
Don't Know/Not Sure	0088
Refused	0099

Research No ___ ___ ___ Page 4 of 13 Ref PJB Lifestyle Quest (1) Excel, Pilot 2

F3 **Lifestyle Questionnaire**

Q Nr.	Code Choice	Code Result	Q Abbrev

1.8 Nationality: [NAT]

Please choose the code from the list below. If you choose 18 (other) then write the country in the space provided.

UAE	0001
Sudan	0002
Kuwait	0003
Jordan	0004
Egypt	0005
Syria	0006
Lebanon	0007
Qatar	0008
Iran	0009
Saudi	0010
Oman	0011
Turkey	0012
Palestine	0013
Kenya	0014
Morocco	0015
Algeria	0016
America	0017
Other	0018
Specify Other _____	
Don't Know/Not Sure	0088
Refused	0099

F3 **Lifestyle Questionnaire**

Q Nr.	Code Choice	Code Result	Q Abbrev

2.0 **Females only**

2.1 **Are you married?** [MAR]

No	0000
Yes	0001
Don't Know/Not Sure	0008
Refused	0009

2.2 **How many children do you have?**

Insert Number of Children [CHILD]

2.3 **Age when you had your first menstrual period?**

Insert Years Old [FIRST]

Don't Know/Not Sure	0088
Refused	0099

2.4 **How regular are your menstrual periods?** [REG]

Regular	0001	(every month)
Irregular	0002	(absent for more than one but less than six months)
Very irregular	0003	(absent for more than six months)
Don't Know/Not Sure	0008	
Refused	0009	

2.5 **Date of last menstrual period:** (dd/mm/yy) [LMP]

F3 **Lifestyle Questionnaire**

Q Nr.	Code Choice	Code Result	Q Abbrev

3.0 Health Information

3.1 How tall are you?

Height in cms [ ] [HGT]

Don't Know/Not Sure 0888

Refused 0999

3.2 How much do you weigh?

Weight in kgs [ ] [WGT]

Don't Know/Not Sure 0888

Refused 0999

3.3 List any medical condition you have or have had which required hospitalization, specialist treatment or continuous medication:

Name of condition-1 [ ] [COND-1]

Name of condition-2 [ ] [COND-2]

Name of condition-3 [ ] [COND-3]

Don't Know/Not Sure 0888

Refused 0999

3.4 Which hand do you write with?

Handed [ ] [HAND]

Right 0001

Left 0002

F3 **Lifestyle Questionnaire**

Q Nr.	Code Choice	Code Result	Q Abbrev

3.5 Are you taking any medication (Females Only: Please state any birth control pill)?

Name of medication-1 [DRUG-1]

Name of medication-2 [DRUG-2]

Name of medication-3 [DRUG-3]

Don't Know/Not Sure 0888

Refused 0999

3.6 Have you ever had an operation?

Name of operation-1 [SURG-1]

Name of operation-2 [SURG-2]

Name of operation-3 [SURG-3]

Don't Know/Not Sure 0888

Refused 0999

3.7 How many times have you ever broken a bone? If you have, state below which bones or body part and how it happened (i.e. a fall, car accident).

No. of times a bone has been broken [BREAKS]

Never 0

Don't Know/Not Sure 0008

Refused 0009

3.8 Details of bones broken:

Name of broken bone-1 [FRACT1]

How? _____

Name of broken bone-2 [FRACT2]

How? _____

Name of broken bone-3 [FRACT3]

How? _____

F3 **Lifestyle Questionnaire**

Q Nr.	Code Choice	Code Result	Q Abbrev

3.9 **If you answered yes to breaking a bone: Did you ever break a bone from only slight injury?** [ ] [FRAGILITY]

No	0000
Yes	0001
Don't Know/Not Sure	0888
Refused	0999

4.0 **Lifestyle Information**

4.1 **Have you ever smoked cigarettes?** [ ] [SMOK]

No	0000 If no move to Q4.4
Yes	0001 If yes move to Q4.2
Don't Know/Not Sure	0888
Refused	0999

4.2 **How many years have you smoked in total?**

Insert number of years [ ] Year [CIG_YR]

Don't Know/Not Sure	0008
Refused	0009

4.3 **How many cigarettes do you (or did you) smoke per day on average?**

Insert number of cigarettes [ ] nr. cigs/day [CIGS_NR]

Don't Know/Not Sure	0008
Refused	0009

F3 **Lifestyle Questionnaire**

Q Nr.	Code Choice	Code Result	Q Abbrev

4.4 How much time per day do you spend in the sun?
Time in the sun refers to the hands and face being uncovered.

Insert number of minutes [ ] mins/day [SUN]

Don't Know/Not Sure 0008

Refused 0009

4.5 How many caffeine containing drinks do you have per week on average?
Caffeine containing drinks include tea, coffee, coca-cola, red bull and others.

Insert number of drinks [ ] drinks/week [CAFF]

Don't Know/Not Sure 0008

Refused 0009

4.6 How many carbonated drinks do you have per week on average?

Carbonated drinks include pepsi, sprite, 7-up, miranda, coca-cola, red bull and others.

Insert number of drinks [ ] drinks/week [CARB]

Don't Know/Not Sure 0008

Refused 0009

4.7 How many drinks of fresh milk do you have per week on average?

Fresh milk includes full fat, skimmed or low fat milk.

Insert number of drinks [ ] drinks/week [MILK]

Don't Know/Not Sure 0008

Refused 0009

F3 **Lifestyle Questionnaire**

Q Nr.	Code Choice	Code Result	Q Abbrev

4.8 Please list any sports which you do, starting with the one you do most often (i.e. swimming, soccer, tennis):

Name of sport-1		[SPORT-1]
Name of sport-2		[SPORT-2]
Name of sport-3		[SPORT-3]

Don't Know/Not Sure 0888

Refused 0999

4.9 How many times do you do each sport per week on average? Please count in units of 15mins (i.e. 1 hour = 4 units)
Please insert number of units for each sport done.

Insert number of units sport-1		units/week	[U_SP_1]
Insert number of units sport-2		units/week	[U_SP_2]
Insert number of units sport-3		units/week	[U_SP_3]

Don't Know/Not Sure 0008

Refused 0009

To find out about how much calcium you eat in a day please fill out the calcium calculator questionnaire. It asks you to think about the foods you ate yesterday. It will give an estimate of the amount of calcium you have in a normal day. THANK YOU VERY MUCH.

Research No __ __ __

F3 **Lifestyle Questionnaire**

Q Nr.	Calcium Intake Description	Portion Size	Nr. of Portions	Total Calcium

Calculate your calcium intake. Think about all the food you ate yesterday. Look through the list of foods below and fill in how many portions of each you had. For example 2 slices of bread is counted as 1 portion of bread.

Please read the questions carefully and try to answer them as accurately as you can. After you have finished filling in this form, the researcher will go through it with you and try to help if you have any questions.

1.0 Each of these foods contains 50 mg of calcium per portion

	50 mg			mg	mg
1.1	Bread	2 slices		0	
1.2	Broccoli, cooked	3/4 cup		0	
1.3	Kidney or Lima beans, Lentils	1 cup		0	
1.4	Orange (fruit, not juice)	1 medium		0	
1.5	Tahini	2 tbsp		0	0

2.0 Each of these foods contains 75 mg of calcium per portion

	75 mg			mg	mg
2.1	Bok Choy or Kale (turnip greens), cooked	1/2 cup		0	
2.2	Chickpeas or Garbanzo beans	1 cup		0	
2.3	Cottage cheese (reg or low fat)	1/2 cup		0	
2.4	Laban	2 Tbsp.		0	
2.5	Ice cream	1/2 cup		0	
2.6	Parmesan cheese	1 Tbsp.		0	
2.7	Almonds	1/4 cup		0	0

Research No ___ ___ ___

Ref PJB Lifestyle Quest (1) Excel, Pilot 2
Source: National Academy of Science
1997

F3

Lifestyle Questionnaire

Q Nr.	Calcium Intake Description	Portion Size	Nr. of Portions	Total Calcium
3.0	Each of these foods contains 150 mg of calcium per portion			
	150 mg			mg
3.1	Baked beans, Soybeans, White beans	1 cup		0
3.2	Ice milk, Frozen yoghurt (reg or low fat)	1/2 cup		0
3.3	Pancakes or Waffles, made with milk	3 medium		0
3.4	Pudding, made with milk	1/2 cup		0
3.5	Soft and semi-soft cheese (mozzarella, feta, camembert, reg or low fat)	1/4" cube		0
3.6	Soup, made with milk	1 cup		0
3.7	Tofu, made with calcium	3 oz		0
				0
4.0	Each of these foods contains 250 mg of calcium per portion			
	250 mg			mg
4.1	Firm cheese (cheddar, swiss, gouda, reg or low fat)	1/4" cube		0
4.2	Processed cheese slices (reg or low fat)	2 slices		0
4.3	Salmon, canned with bones	1/2 can		0
4.4	Sardines, canned with bones	1/2 can		0
4.5	Yoghurt, fruit flavoured (reg or low fat)	3/4 cup		0
				0
5.0	Each of these foods contains 300 mg of calcium per portion			
	300 mg			mg
5.1	Milk - skim, 1%, 2%, whole, buttermilk or chocolate	1 cup		0
5.2	Calcium-fortified beverages, (e.g. soy, rice)	1 cup		0
5.3	Skim milk powder	1/3 cup		0
5.4	Yoghurt, plain (reg or low fat)	3/4 cup		0
				0
	Total Calcium Intake mg			**0**

Research No __ __ __

Ref PJB Lifestyle Quest (1) Excel, Pilot 2
Source: National Academy of Science
1997

APPENDIX G – IPAQ Exercise Questionnaire

F4 **Research No** _ _ _

Physical Activity Questionnaire

READ: I am going to ask you about the time you spent being physically active in the last 7 days. Please answer each question even if you do not consider yourself to be an active person. Think about the activities you do at work, as part of your house and garden work, to get from place to place, and in your spare time for recreation, exercise or sport.

READ: Now, think about all the *vigorous* activities which take *hard physical effort* that you did in the last 7 days. Vigorous activities make you breathe much harder than normal and may include heavy lifting, digging, aerobics, or fast bicycling. Think only about those physical activities that you did for at least 10 minutes at a time.

1. During the **last 7 days**, on how many days did you do **vigorous** physical activities?

   _____ Days per week [VDAY; Range 0-7, 8,9]

   8. Don't Know/Not Sure

   9. Refused

   [**Interviewer clarification**: Think only about those physical activities that you do for at least 10 minutes at a time.]

   [**Interviewer note**: If respondent answers zero, refuses or does not know, skip to Question 3]

2. How much time did you usually spend doing **vigorous** physical activities on one of those days?

   __ __ Hours per day [VDHRS; Range: 0-16]

   __ __ __ Minutes per day [VDMIN; Range: 0-960, 998, 999]

   998. Don't Know/Not Sure

   999. Refused

   [**Interviewer clarification**: Think only about those physical activities you do for at least 10 minutes at a time.]

   [**Interviewer probe**: An average time for one of the days on which you do vigorous activity is being sought. If the respondent can't answer because the pattern of time spent varies widely from day to day, ask: "How much time in total would you spend **over the last 7 days** doing vigorous physical activities?"

   __ __ Hours per week [VWHRS; Range: 0-112]

   __ __ __ __Minutes per week [VWMIN; Range: 0-6720, 9998, 9999]

   9998. Don't Know/Not Sure

   9999. Refused

F4

Research No _ _ _

READ: Now think about activities which take *moderate physical effort* that you did in the last 7 days. Moderate physical activities make you breathe somewhat harder than normal and may include carrying light loads, bicycling at a regular pace, or doubles tennis. Do not include walking. Again, think about only those physical activities that you did for at least 10 minutes at a time.

3. During the **last 7 days**, on how many days did you do **moderate** physical activities?

____ Days per week [MDAY; Range: 0-7, 8, 9]

8. Don't Know/Not Sure

9. Refused

[**Interviewer clarification**: Think only about those physical activities that you do for at least 10 minutes at a time]

[**Interviewer Note**: *If respondent answers zero*, refuses or does not know, skip to Question 5]

4. How much time did you usually spend doing **moderate** physical activities on one of those days?

__ __ Hours per day [MDHRS; Range: 0-16]

__ __ __ Minutes per day [MDMIN; Range: 0-960, 998, 999]

998. Don't Know/Not Sure

999. Refused

[**Interviewer clarification**: Think only about those physical activities that you do for at least 10 minutes at a time.]

[**Interviewer probe**: An average time for one of the days on which you do moderate activity is being sought. If the respondent can't answer because the pattern of time spent varies widely from day to day, or includes time spent in multiple jobs, ask: "What is the total amount of time you spent over the **last 7 days** doing moderate physical activities?"

__ __ __ Hours per week [MWHRS; Range: 0-112]

__ __ __ __Minutes per week [MWMIN; Range: 0-6720, 9998, 9999]

9998. Don't Know/Not Sure

9999. Refused

F4

Research No _ _ _

READ: Now think about the time you spent walking in the last 7 days. This includes at work and at home, walking to travel from place to place, and any other walking that you might do solely for recreation, sport, exercise, or leisure (eg shopping).

5. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time?

____ Days per week [WDAY; Range: 0-7, 8, 9]

8. Don't Know/Not Sure

9. Refused

[**Interviewer clarification**: Think only about the walking that you do for at least 10 minutes at a time.]

[**Interviewer Note**: *If respondent answers zero,* refuses or does not know, skip to Question 7]

6. How much time did you usually spend **walking** on one of those days?

__ __ Hours per day [WDHRS; Range: 0-16]

__ __ __ Minutes per day [WDMIN; Range: 0-960, 998, 999]

998. Don't Know/Not Sure

999. Refused

[**Interviewer probe**: An average time for one of the days on which you walk is being sought. If the respondent can't answer because the pattern of time spent varies widely from day to day, ask: "What is the total amount of time you spent walking over **the last 7 days**?"

__ __ __ Hours per week [WWHRS; Range: 0-112]

__ __ __ __Minutes per week [WWMIN; Range: 0-6720, 9998, 9999]

9998. Don't Know/Not Sure

9999. Refused

F4

Research No _ _ _

READ: Now think about the time you spent sitting on week days during the last 7 days. Include time spent at work, at home, while doing course work, and during leisure time. This may include time spent sitting at a desk, visiting friends, reading or sitting or lying down to watch television.

7. During the last 7 days, how much time did you usually spend ***sitting*** on a **week day**?

__ __ Hours per weekday [SDHRS; 0-16]

__ __ __ Minutes per weekday [SDMIN; Range: 0-960, 998, 999]

998. Don't Know/Not Sure

999. Refused

[**Interviewer clarification**: Include time spent lying down (awake) as well as sitting]

[**Interviewer probe**: An average time per day spent sitting is being sought. If the respondent can't answer because the pattern of time spent varies widely from day to day, ask: "What is the total amount of time you spent *sitting* last **Wednesday**?"

__ __ Hours on Wednesday [SWHRS; Range 0-16]

__ __ __ Minutes on Wednesday [SWMIN; Range: 0-960, 998, 999]

998. Don't Know/Not Sure

999. Refused

APPENDIX H – Personal Information Form

Strictly **Private** and **Confidential**. This information only for research team use

Medical Diagnostic Imaging
College of Health Sciences
University of Sharjah

PERSONAL INFORMATION

Research Number __ __ __

The information you give below is for contacting you again after today to arrange for further tests, if you have agreed to that. It will be kept confidential. This form will be stored in a locked filing cabinet, in a locked office. For all other research documentation, only your assigned research number will be used.

DWC student No.__ __ __ __ __ __ __ __

Name _____ _____ _____

Tel Mob __ __ __ __ __ __ __

Tel Home __ __ __ __ __ __ __ __ __ __

Address _____

Emirate _____

Start Date __ __ / __ __ / __ __ __ __ (DD/MM/YYYY)

APPENDIX I – Research Procedure Instructions

Research Procedure Instructions

Medical Diagnostic Imaging
College of Health Sciences
University of Sharjah

Bone Mineral Density, Diet and Exercise in Arab Students

Research Project, Stage 1 (Lifestyle, exercise and QUS):

Instruments/ Forms required:

1. Personal information form
2. F1 Information brochure
3. F2 Consent Form
4. F3 Lifestyle Questionnaire (11 pages)
5. F4 Physical Activity Questionnaire (4 pages)
6. Results sheet for QUS

Equipment required:

1. Weighing scales
2. Height measurement equipment
3. Sahara ultrasound machine
4. Coupling gel
5. Alcohol swabs
6. Wet wipes

Preparation for session:

1. Ensure all above items are present in adequate numbers, normal room temperature is selected on air conditioning unit
2. Switch on Sahara, allow to stand for 1 hour for machine to normalize to room temperature
3. After 1 hour, perform QA test on the Sahara using the manufacturers phantom
4. If QA sucessful, set up machine for first scan

Instructions for research procedure:

1. Researcher introduces themself to the volunteer
2. Thanks the student for considering becoming a volunteer
3. Ensures that the student is 18 or above, understands English and considers themself to be healthy
4. Asks the student to read F1, answers any questions raised
5. Asks the student to sign F2, then fills in the personal info sheet assigning research number, transfer research number to all other documents
6. Measures the students height and weight
7. Asks the student to complete F3, then goes through it after completion with the student to check for completeness and help with difficulties
8. Reads F4 to the student and fills in answers as supplied

P Bell Instructions

Research Procedure Instructions

9. Performs QUS scan on the non-dominant heel, opposite side to that used for writing, prints result
10. Examines result, if no error message shown writes result on QUS result sheet, if error message then remove foot and rescan
11. If QUS result is **normal**, not less than -1 standard deviation from the reference range, tells student their result and explains significance including that the result has been compared to a reference range of healthy young European women and that no reference range is available yet for Arab women
12. If QUS result is **below normal**, less than -1 standard deviation (e.g. -1.6 or -2.3) then inform the student that the result indicates a lower bone density than expected for a healthy young European female. The student should be advised not to be concerned but to consult their doctor for further advice
13. The researcher should be aware that the machine may have difficulty in measuring very large persons and not all expected values may be shown on the results
14. Reminds the student that they may be called back for DXA if appropriate
15. Thanks the student for their participation
16. Cleans and resets the Sahara machine
17. File documents, info sheet seperately from other sheets

Researcher: P Bell, BSc. (Hons) Applied Radiography, Dip. Radionuclide Imaging, Dip. College Radiographers, Cert. Bone Density ISCD/IOF

Assisstants: 1/ _____
2/ _____
3/ _____

P Bell

Instructions

APPENDIX J – Poster

Attention students!

STOP!

Are your bones as strong as they should be?

THINK!

Is your diet healthy?
Do you exercise enough?

TAKE ACTION!

Ask Ms.Bell about the research project
"Bone Mineral Density, Diet & Exercise in
Students at the University of Sharjah, UAE"

Contact: W8-002 Ms. Penelope Bell
Tel: Office-(06) 5050803. Mobile-6545704

APPENDIX K – Information for participants, pilot

Osteoporosis and Bone Density Information

- **Osteoporosis is a disease in which bones become fragile or weak and may easily break**
- **After 50 years of age, 1 in 3 women and 1 in 12 men will suffer from Osteoporosis**
- **From birth to the early 20's a store of healthy bone is being built up in the skeleton until the Peak Bone Mass (the maximum amount of bone) is reached**
- **From about age 35 onwards the body naturally and gradually loses its stores of bone**
- **The more bone you build up, the more bone stores you will have, the longer you will live before your bones become so weak that they break**

Are your bones as strong as they should be?

Have your bone density measured

REMEMBER:
***eating calcium rich foods**
***doing regular weight bearing exercise**
***avoiding fizzy drinks**
***stopping smoking**
***reducing caffeine intake**
***getting 15 minutes of sunlight on hands & face per day**

Will Help Prevent Osteoporosis

Bone Density Measurement

- **The Medical Diagnostic Imaging department in the College of Health Sciences is offering bone density testing for World Health Day, organized by the World Health Organization WHO**

- **The purpose of bone density measurement is to compare your bone density to a normal reference range. A low reading could lead to Osteoporosis later on in life**

- **Your bone density will be measured in your heel bone using the Hologic Sahara ultrasound machine**

- **Ultrasound is safe, radiation free and painless**

- **You will be asked some simple questions about yourself and your lifestyle**

- **To do the test you will uncover your foot. While sitting in a chair your foot will be placed in the machine**

- **The test will take only a minute**

- **Two soft pads touch either side of your heel and sound waves pass through the bone**

- **You will then be given your test results**

- **Further information on bone density, and your result, can be obtained from your own doctor**

- **The results from your scan may be used for research purposes but your name will never be used, only a code number**

APPENDIX L – Consent and Lifestyle Questionnaire, Pilot

Scan Sheet

Date----------

Time----------

Name----------

Student Number----------

Date of Birth----------

Age----------years

Country of birth----------

Place lived in the longest----------

Nationality----------

Height----------cm

Weight----------kgs

Male--------- Female----------

Heel scanned? R L

Handed? R L

I have read and understood the information given to me and I consent to have a heel ultrasound scan, and for the data to be used for research if required

Signed----------

Physical exercise during the past 7 days: No
Yes What type?
Swimming Riding Cycling
Running Basketball Other----------
How often?
Daily Three times/week Once/week

Foods eaten in the last 7 days:
Any of the foods on the calcium-rich foods list?

State the food and how often eaten

How many drinks of milk do you have?
None One/day Two/day Three or more/day
One/week Two/week ----------

Do you smoke? No Yes----------per day

How many fizzy drinks do you have?
None One/day Two/day Three or more/day
One/week Two/week ----------

How many caffeine containing drinks do you have? (tea/coffee)
None One/day Two/day Three or more/day
One/week Two/week ----------

Do you have any medical condition? No
Yes----------

Are you taking any medication regularly? No
Yes----------

Have you ever broken a bone? No
Yes----------

Females only

Do you have regular periods? Yes No

Did your periods start before the age of 17? Yes No-----

Do you cover fully hands and face? No Yes

If yes, how often do you go in the sun uncovered?

APPENDIX M – List of Calcium Containing Foods, Pilot

Calcium-rich foods

Food	Quantity	Mg of calcium
Dairy products		
Milk skimmed	⅓ pt / 190ml	235
Milk semi-skimmed	⅓ pt / 190ml	231
Milk whole	⅓ pt / 190ml	224
Milk soya*	⅓ pt / 190ml	25
Cream double	3½ oz / 100g	50
Cream single	3½ oz / 100g	91
Cream whipping	3½ oz / 100g	62
Cheese cheddar	3½ oz / 100g	720
Cheese low fat (hard)	3½ oz / 100g	840
Cheese Camembert	3½ oz / 100g	350
Cheese Cottage	3½ oz / 100g	73
Cheese Edam	3½ oz / 100g	770
Yogurt fruit low-fat	3½ oz / 100g	150
Yogurt fruit	3½ oz / 100g	160
Fromage frais fruit	3½ oz / 100g	86
Ice-cream dairy	3½ oz / 100g	130
Ice-cream non-dairy	3½ oz / 100g	120
Custard from powder	3½ oz / 100g	140
Rice pudding	3½ oz / 100g	93

Food	Quantity	Mg of calcium
Fish		
Pilchards in tomato sauce	3½ oz / 100g	300
Sardines in tomato sauce	3½ oz / 100g	460
Sardines in oil	3½ oz / 100g	550
Whitebait fried	3½ oz / 100g	860
Salmon tinned	3½ oz / 100g	93
Vegetables		
Curly kale boiled	3½ oz / 100g	150
Okra stir fried	3½ oz / 100g	220
Spinach boiled	3½ oz / 100g	160
Spring greens boiled	3½ oz / 100g	75
Watercress	3½ oz / 100g	170
Pulses, beans and seeds		
Red kidney beans	3½ oz / 100g	71
Tofu steamed**	3½ oz / 100g	510
Green/French beans	3½ oz / 100g	56
Baked beans	3½ oz / 100g	53
Sesame seeds	3½ oz / 100g	670
Tahini (sesame paste)	3½ oz / 100g	680

Food	Quantity	Mg of calcium
Cereal products		
White bread*	1 slice	33
Wholemeal bread	1 slice	16
Muesli Swiss style	3½ oz / 100g	110
Special K	3½ oz / 100g	70
Ready Brek	3½ oz / 100g	65
Snacks		
Tortilla chips	3½ oz / 100g	150
Milk chocolate	3½ oz / 100g	220
White chocolate	3½ oz / 100g	270
Creme eggs	3½ oz / 100g	120
Kit Kat	3½ oz / 100g	200
Mars Bar	3½ oz / 100g	160
Fruit Gums	3½ oz / 100g	360
Fruit		
Apricots dried	3½ oz / 100g	92
Figs dried	3½ oz / 100g	250
Currants	3½ oz / 100g	93
Mixed peel	3½ oz / 100g	130
Olives in brine	3½ oz / 100g	61
Orange peeled	3½ oz / 100g	33

Food	Quantity	Mg of calcium
Convenience food		
Moussaka homemade	3½ oz / 100g	81
Lasagne frozen	3½ oz / 100g	71
Sausage low-fat grilled	3½ oz / 100g	130
Cornish pasty	3½ oz / 100g	60
Omelette cheese	3½ oz / 100g	280
Quiche cheese and egg	3½ oz / 100g	260
Macaroni cheese	3½ oz / 100g	170
Pizza cheese and tomato	3½ oz / 100g	210

* may be calcium enriched

** different products vary considerably

Please note, the calcium contents (with the exception of milk and bread), have been calculated per 100g and are therefore not portion size. This has been done to make comparisons between various foods easier.

Ref: Information provided courtesy of The Royal Society of Chemistry and Ministry of Agriculture, Fisheries and Food publication 'The Composition of Foods' 1992.

APPENDIX N – Exercise Information for Healthy Bones, Pilot

Summary

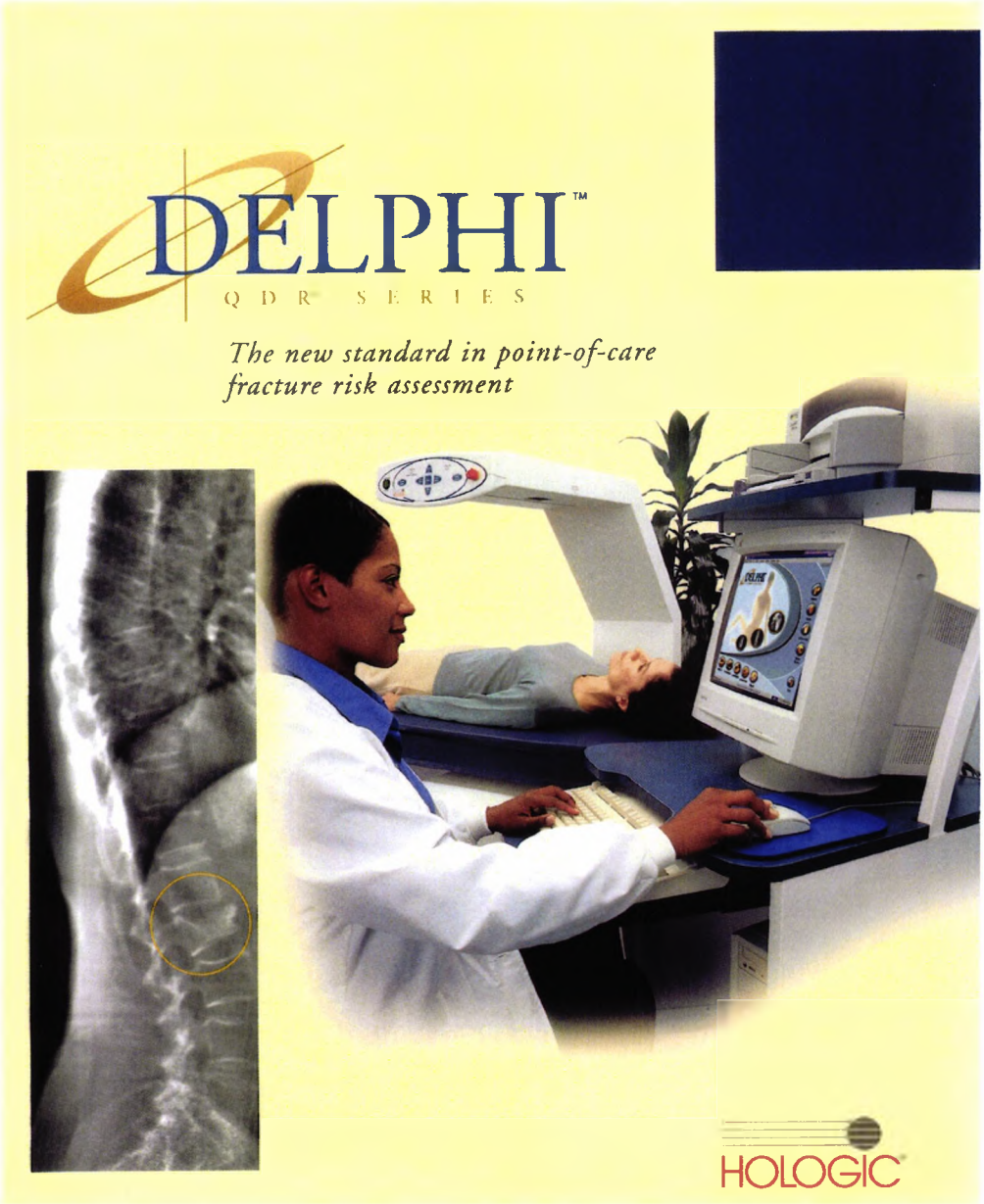
- Weight-bearing exercise helps to increase and maintain bone density
- Choose activities which you enjoy
- Short bursts of varied vigorous activity are most effective
- Brief high impact exercise is the best activity for young people

Recommended kinds of exercise

- **Jumping/skipping** – 50 jumps a day *(for young people)*
  or
  Stair-climbing – 10 flights a day *(for older people)*
- **Jogging** – 3 times a week *(for young people)*
  or
  Intermittent jogging – 3 times a week *(for older people)*
- **Exercise-to-music** classes
- **Weight-training** – high loads and few repetitions
- **Field sports, racket sports, dancing** such as tap or Irish dancing

APPENDIX O – Equipment Details (QUS and DXA)

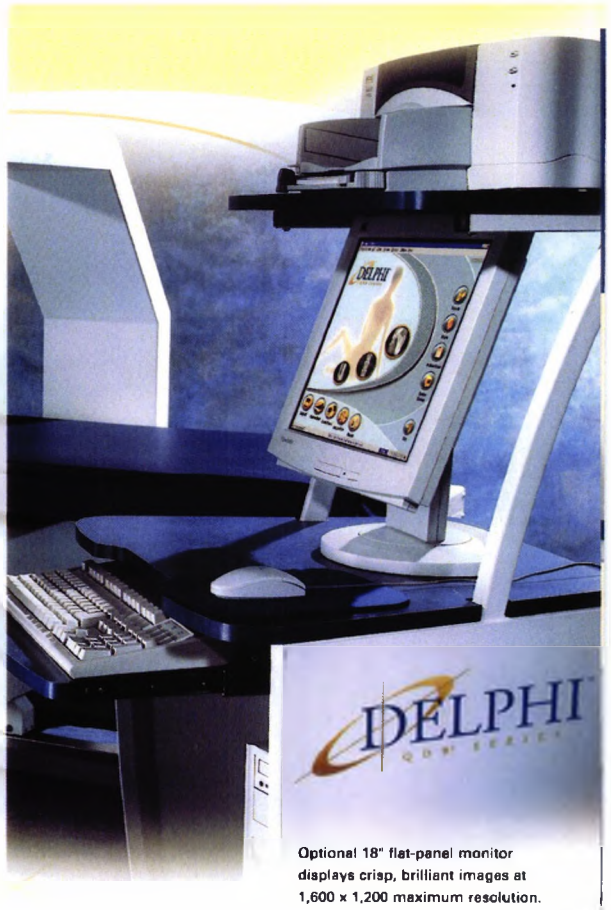
DXA Hologic



Additional Delphi

FEATURES

- Complete system, including advanced, high-speed CPU, large monitor, and fast, color printer
- 3.5-in. LS 120 Superdisk Drive for scan archiving
- CD ROM for support programs
- **Anthropomorphic Spine Phantom**, used for quality control, assures consistently accurate measurements without the need for waterbaths to perform system calibration.
- QDR's patented **Automatic Internal Reference System** automatically maintains pixel-by-pixel calibration without operator involvement and assures long-term precision.
- **Image Repositioning** makes obtaining the perfect scan easy. With the push of a button, operators can interrupt scanning to adjust the image on screen, without having to reposition the patient on the table.
- **Reanalysis** lets you repeatedly reanalyze scan information—stored as raw data—without rescanning, even a year or more after the initial scan.
- **Scoliotic Spine Analysis** tailors vertebral BMD assessment to the unique curvature of patients with scoliosis.
- **Automatic Bone Mapping** calculates the soft tissue and bone map of any scan without operator involvement.
- **Automatic Locate** feature internally records and monitors the location of patient data saved to a storage media, eliminating the need to log patient data.
- **Context Sensitive Help Menu** provides an overview and virtual "walk through" of Delphi's operation and capabilities. A single click on a topic button produces instructions on scanning, analysis, and data management.
- **Practice Development Guide** contains two CDs with ready-to-print marketing and patient education materials to build public awareness and help you take full advantage of Delphi's practice-building potential.



Optional 18" flat-panel monitor displays crisp, brilliant images at 1,600 x 1,200 maximum resolution.

References

1. Melton LJ III, Lane AW, Cooper C, Eastell R, O'Fallon WM, Riggs, BL. Prevalence and incidence of Vertebral Deformities. Osteoporosis Int. 1993;3:113-119.
2. Ross PD, Davis JW, Epstein RS, Wasnich RD. Pre-existing fractures and bone mass predict vertebral fracture incidence in women. Ann Intern Med. 1991;114(11):919-23.
3. Kotowicz MA, Melton LJ III, Cooper C, Atkinson EJ, O'Fallon WM, Riggs BL. Risk of hip fracture in women with vertebral fracture. J Bone Miner Res. 1994;9(5):599-606.
4. Ross PD, Genant HK, Davis JW, Miller PD, Wasnich RD. Predicting vertebral fracture incidence from prevalent fractures and bone density among non-black, osteoporotic women. Osteoporos Int. 1993;3(3):120-126.
5. Davis JW, Grove JS, Wasnich RD, Ross PD. Spatial relationships between prevalent and incident spine fractures. Bone. 1999;24(3):261-4.
6. Pouilles JM, Tremollieres F, Ribot C. Spine and femur densitometry after menopause:are both sides necessary in the assessment of risk of Osteoporosis. CalcifTissue Int. 1993 May; 52 (5): 344-7

QUS Phalanges

7 TECHNICAL DATA

7.1 Central Monitoring Unit Bone Profiler BP01 (CMU)

Manufacturer:	IGEA S.r.l.
Model:	Bone Profiler BP01
Power supply:	110 - 230 VAC
Frequency:	50 - 60 Hz
Maximum input power:	60 VA
Room temperature:	10 - 40° C
Fuses:	2 x T 1 A - 5 x 20 mm (110 - 230 VAC)

7.1.1 Classification:

Classification (IEC 601-1):	Class I with type BF applied part
Classification (Dir. EEC 93/42)	Class IIa

7.1.2 Use conditions:

Continual working device not to be used in the presence of anaesthetic mixture flammable with air, with oxygen, with nitrous oxide.

Common device with cover unprotected against the penetration of liquids.

7.1.3 Mechanical characteristics:

Dimensions:	36l x 48p x 32h cm
Weight:	14 kg

7.1.4 Characteristics of the ultrasound probes signal:

Type of signal:	Square wave
Amplitude:	24 Vpp
Frequency:	1,25 MHz
Repetition time:	102,4 µsec
US beam output power:	1,63 mW/cm² ± 6,3%

7.2 Carrying and storing environmental conditions

The Bone Profiler BP01 equipment can be carried and stored without suffering any deterioration in the environmental conditions described below:

- room temperature from -40 to +70 °C
- relative humidity from 10 to 90%
- atmospheric pressure from 500 to 1060 hPa

The device must be placed inside the original package with the relevant protections.

QUS Heel, Achilles

Revised 7/99D

Achilles Express Ultrasonometer (part #6550)

- Dimensions (W x H x D): 25.4 x 30.5 x 61cm (10 x 12 x 24 in)
- Weight: 10 kg (22 lbs.)

Measurements *In Vivo*

- Stiffness Index (%Young Normal) ± 2%

Methods and Transducers

- Fluid-coupled, through-transmission
- Quarter wave-matched, broadband single element
- Center frequency = 0.5 MHz

Analysis

- Real-time, point-by-point analog/digital conversion
- Smart detection algorithm, Discrete Fourier Transform
- Simultaneous Stiffness/SOS/BUA determination

Fluid Coupling System

- Heated coupling fluid (33°C)
- Water-soluble Ultrasonic Gel

Output/Display

- Stiffness Index vs. %Young Adult and %Age Matched

Power

- 95-240V AC
- 50-60 Hz
- 4 Amps

Operating Temperature Range

15-35 ° C (59-95 ° F)

Operating Humidity Range

20-80%

Compliance to Standards

IEC 601-1 (Type B)

IEC 601-1-2

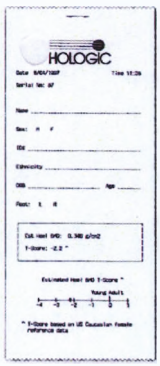
UL 2601-1

CSA 22.2 No. 601.1

QUS heel, Sahara

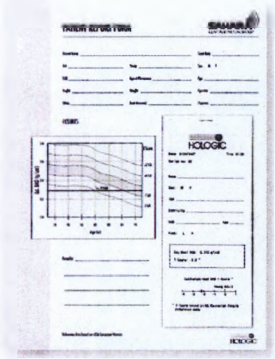
IMMEDIATE RESULTS AND DOCUMENTATION

Within seconds after completing the test, Sahara's LCD panel displays BMD and T-score results. BMD is the accepted international standard for measuring bone density. Following guidelines set by the World Health Organization, T-scores help physicians identify patients at risk of developing osteoporosis.



Sahara's internal printer provides hardcopy documentation of test results in 20 seconds.

The Sahara supports multiple languages including English, Spanish, French, Italian, German, Portuguese and Slavic.



Transfer patient information and test results to the supplied Patient Report Form for a permanent record. Plotting the T-score and Z-score on the reference curve section provides an easy-to-read graphic representation of test outcome and patient bone health status.

SAHARA
CLINICAL BONE SONOMETER™

1. ***Radiation-free***
   Improves patient acceptance. Registered x-ray technologist not required to operate system.

2. ***Simple to Operate***
   Pressing one button starts and completes the test. The staff member who takes patients' height and weight can operate the unit.

3. ***Compact and Lightweight***
   Just 10 Kg (22 lbs), Sahara comes equipped with a built-in handle for portability. The entire space required to perform a bone density test with Sahara, including chair, is less than the footprint of a standard office desk.

4. ***Requires a Minimum of Operator Training***
   Supplied 20-minute training video covers all the instruction needed for basic operation.

5. ***Rapid Patient Throughput***
   The test takes less than one minute to complete. There's nothing faster on the market.

6. ***Reliable Positioning Device***
   Assures high reproducibility of results and minimizes operator influence.

7. ***Built-in Microprocessor and Printer***
   External computer and printer not required. Saves space and contributes to ease of operation.

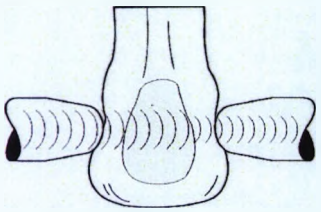
8. ***Estimates BMD, T-Score and Z-Score***
   Sahara is the only ultrasound bone densitometer that estimates BMD and determines BMD T-scores. Sahara results can also be used to derive Z-scores which are important for predicting future fracture risk.

9. ***Multiple Language Support***
   Operator prompts, results and printed hardcopy are available in English, French, Spanish, Portuguese, German, Italian and other languages.

10. ***Low Cost***
    Sahara costs less than half the price of a DXA (dual-energy x-ray absorptiometry) bone densitometer, the "gold standard" of bone densitometry.

SAHARA...FIRST AND ONLY ULTRASOUND BONE DENSITOMETER THAT ESTIMATES BMD AND CALCULATES BMD T-SCORES

ULTRASOUND MEASUREMENT



Sahara transducers send and receive the ultrasound signal through the calcaneus.

Bone mineral density or BMD, expressed in g/cm², has long been accepted as the international standard for assessing bone status. The Sahara Clinical Bone Sonometer is the first and only bone densitometer that uses non-ionizing ultrasound to estimate BMD.

Sahara measures the transmission of high-frequency sound waves (ultrasound) through the heel. From the measured signal, three ultrasound parameters are simultaneously determined: Speed of Sound (SOS), Broadband Ultrasonic Attenuation (BUA), and the Quantitative Ultrasound Index (QUI)—sometimes called "stiffness"—which is a combination of SOS and BUA. The Sahara system software automatically estimates BMD from the QUI/stiffness value.

SAHARA CALCULATES BMD T-SCORES AND ENABLES DETERMINATION OF FRACTURE RISK

Sahara's built-in microprocessor compares patient BMD results to a large reference database of sex-matched, young adult subjects to produce a *T-score*. T-scores facilitate classification of patients at risk of developing osteoporosis, using internationally accepted guidelines established by the World Health Organization (W.H.O.).

W.H.O. CLASSIFICATION BY T-SCORE

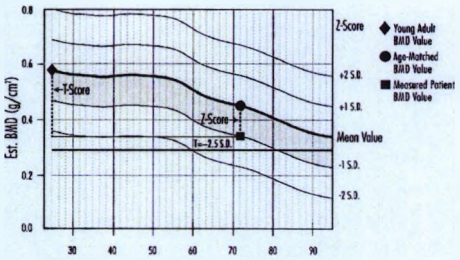
(SD = Standard Deviation)

T-SCORE	CLASSIFICATION
T > – 1.0 SD	Normal
-1.0 SD >T> -2.5 SD	Osteopenic
T < – 2.5 SD	Osteoporotic

World Health Organization, Kanis, et al. Osteo. Int'l., Vol. 4, pg 368-381 (1994)

T-scores, plus information provided by patients about their medical history, age, lifestyle, etc., help physicians assess a patient's risk of developing osteoporosis.

Z-scores—the comparison of BMD results with age-matched peers—can also be derived from BMD and are used to estimate risk of future fracture. For this purpose, a reference database is required.



Sahara has the largest reference database of any ultrasound system for bone assessment.

REFERENCES

1. *Miller P, Epstein S. "Bone Mass Measurements, The Case for Selected Screening?," Trends in Endo and Metab. Vol 8, No. 4, May/June 1997, p 160.*
2. *"Assessment of Fracture Risk and Its Application to Screening for Postmenopausal Osteoporosis," Report of a WHO Study Group, World Health Organization, Geneva, 1994*
3. *"Report on the Commission on the State of Women's Health in the European Community." Commision of the European Communities, Brussels, 22.05.1997 COM(97) 224*
4. *Langton CM, Palmer SB, Porter RW 1984 The measurement of broadband ultrasonic attenuation in cancellous bone. Eng Med 13(2):89-91.*
5. *Cummings SR, Black DM, Nevitt MC, Browner WS, Cauley JA, Genant HK, Mascioli SR, Scott JC, Seeley DG, Steiger P, et al. 1990 Appendicular bone density and age predict hip fracture in women. The Study of Osteoporotic Fractures Research Group. Jama 263(5):665-8.*
6. *Black DM, Cummings SR, Genant HK, Nevitt MC, Palermo L, Browner W 1992 Axial and appendicular bone density predict fractures in older women. J Bone Miner Res 7(6):633-8.*
7. *Cummings SR, Black DM, Nevitt MC, Browner W, Cauley J, Ensrud K, Genant HK, Palermo L, Scott J, Vogt TM 1993 Bone density at various sites for prediction of hip fractures. The Study of Osteoporotic Fractures Research Group. Lancet 341(8837):72-5.*
8. *Nevitt MC, Johnell O, Black DM, Ensrud K, Genant HK, Cummings SR 1994 Bone mineral density predicts non-spine fractures in very elderly women. Study of Osteoporotic Fractures Research Group. Osteoporos Int 4(6):325-31*
9. *Cummings SR, Black D 1995 Bone mass measurements and risk of fracture in Caucasian women: a review of findings from prospective studies. Am J Med 98(2A):24S-28S.*
10. *Black DM, Cummings SR, Karpf DB, Cauley JA, Thompson DE, Nevitt MC, Bauer DC, Genant HK, Haskell WL, Marcus R, Ott SM, Torner JC, Quandt SA, Reiss TF, Ensrud KE 1996 Randomised trial of effect of alendronate on risk of fracture in women with existing vertebral fractures. Fracture Intervention Trial Research Group. Lancet 348(9041):1535-41.*
11. *Hans D, Dargent-Molina P, Schott AM, Sebert JL, Cormier C, Kotzki PO, Delmas PD, Pouilles JM, Breart G, Meunier PJ 1996 Ultrasonographic heel measurements to predict hip fracture in elderly women: the EPIDOS prospective study. Lancet 348(9026):511-4.*
12. *Bauer, et al. Broadband ultrasound attenuation predicts fractures strongly and independently of densitometry in older women. A prospective study. Study of Osteoporotic Fractures Research Group. Arch. Intern. Med. Vol. 157, 1997: 629-34*

SPECIFICATIONS

IEC 601-1 Class 1 Type BF. IPXO. The UL classification for the Sahara Clinical Bone Sonometer is Class 1 Equipment.

Measurement Site: Calcaneus (heel)

Coupling Method: Sahara Coupling Gel only

Measurement Time: Less than 10 seconds

Patient Reports: Built-in Strip Printer

Measurements: Estimated heel BMD and Quantitative Ultrasound Index (QUI), obtained from measured BUA and SOS

Estimated Heel BMD:
- C.V.: 3%
- Absolute Precision: 0.014g/cm²

QUI:
- C.V.: 2.6%
- Absolute Precision: 2.2

QC Check: Daily, utilizing supplied QC phantom

Operating temperature range: 60° - 100° F (15° - 37.7° C)

Operating humidity range: 20-80% R.H. non condensing

Shipping and Storage:
- Ambient Temperature: -40° to 120° F (-40° C to 49° C)
- Relative Humidity: 20% to 95%
- Atmospheric Pressure: 500 hPa to 1060 hPa

Power Requirements:
- 100-240 VAC, 50-60 Hz, <60 watts (automatically adjusts from 100 VAC to 240 VAC, and 50 Hz to 60 Hz)

CPU: Embedded microprocessor

Ultrasonic Energy:
- I_{sppa} < 0.001 W/cm² typical
- I_{spta} < 0.001 mW/cm² typical
- Mechanical Index (MI) < 0.01 typical
- Pulse Repetition Rate (PRR) < 200 Hz

Safety Standards: IEC601-1, UL2601-1, CSA C22.2

Size: 17"D x 14"W x 12"H (43cm x 36cm x 30cm)

Weight: 22 lb. (10kg)

APPENDIX P– Numbers of Students Registered

UNIVERSITY OF SHARJAH
Admission and Registration Dept.

Statistics by Faculty and Major
For the Spring2004-2005 Semester

Page: 1/3
Date: 21-08-2005 11:48
User: AD_BELL
Ref.: ROS_609E

Faculty: Arts & Sciences			
Major	**Advised**	**Registered**	**Period**
B. Arabic Language & Literature	157	157	157
B. Computer Science	140	140	140
B. English Language & Literature	93	93	93
B. History & Islamic Civilization	93	93	93
B. Sociology	131	131	131
General Diploma in Education	15	15	15
M.A. in History & Islamic Civilization	22	22	22
M.A.in Arabic Language & Literature	24	24	24
M.Sc. in Computer Science	17	17	17
Total	**692**	**692**	**692**
Faculty: Business & Management			
Major	**Advised**	**Registered**	**Period**
B. in Accounting	150	150	150
B. in Business Administration	233	233	233
B. in Management Information System	283	283	283
B. in Public Administration	94	94	94
Executive Master in Business Administration	62	62	62
Total	**822**	**822**	**822**
Faculty: Career Development			
Major	**Advised**	**Registered**	**Period**
DCD - Undecided	410	410	410
Diploma in Career Development - Acounting	85	85	85
Diploma in Career Development - Informatio	146	146	146
Diploma in Career Development - Manageme	171	171	171
General Diploma in Administrative Work	117	117	117
Higher Diploma in Career Development for I	0	0	0
Total	**929**	**929**	**929**
Faculty: Communication			
Major	**Advised**	**Registered**	**Period**
B. in Communication.	614	614	614
M.A. in Communication	5	5	5
Total	**619**	**619**	**619**
Faculty: Dentistry			
Major	**Advised**	**Registered**	**Period**
B. in Dentistry	65	65	65
Total	**65**	**65**	**65**

UNIVERSITY OF SHARJAH
Admission and Registration Dept.

Statistics by Faculty and Major
For the Spring2004-2005 Semester

Page: 2/3
Date: 21-08-2005 11:48
User: AD_BELI.
Ref.: ROS_609E

Faculty: Educational Centers			
Major	**Advised**	**Registered**	**Period**
IEP-Business	146	146	146
IEP-Computer Sc	23	23	23
IEP-Dentistry	49	49	49
IEP-Engineering	106	106	106
IEP-English	46	46	46
IEP-Fine Arts	10	10	10
IEP-Health	70	70	70
IEP-Medicine	42	42	42
IEP-Pharmacy	29	29	29
Total	**521**	**521**	**521**
Faculty: Engineering			
Major	**Advised**	**Registered**	**Period**
B. Architectural Engineering	28	28	28
B. Computer Engineeering	235	235	235
B. in Civil Engineering	180	180	180
B. in Electrical and Electronic Engineering	162	162	162
MSc. in Civil Engineering	5	5	5
Total	**610**	**610**	**610**
Faculty: Fine Arts			
Major	**Advised**	**Registered**	**Period**
Bachelor of Fine Art	43	43	43
Total	**43**	**43**	**43**
Faculty: Health Sciences			
Major	**Advised**	**Registered**	**Period**
B. Health Services Administration	55	55	55
B. Medical Diagnostic Imaging	46	46	46
B. Medical Lab Technology	107	107	107
B. Physiotherapy	63	63	63
B.Sc in Environmental Health and Nutrition	9	9	9
B.Sc in Nursing	35	35	35
B.Sc. in Nursing	65	65	65
Diploma in Food Safety	23	23	23
Total	**403**	**403**	**403**
Faculty: Law.			
Major	**Advised**	**Registered**	**Period**
Bachelor of Law	677	677	677
M. in Private Law	7	7	7
Total	**684**	**684**	**684**
Faculty: Medicine			
Major	**Advised**	**Registered**	**Period**
B. in Medicine	60	60	60
Total	**60**	**60**	**60**

UNIVERSITY OF SHARJAH
Admission and Registration Dept.

Statistics by Faculty and Major
For the Spring2004-2005 Semester

Page: 3/3
Date: 21-08-2005 11:48
User: AD_BELL
Ref.: ROS_609E

Faculty: Pharmacy				
	Major	**Advised**	**Registered**	**Period**
	B.in Pharmacy	55	55	55
	Total	**55**	**55**	**55**
Faculty: Shari'a & Islamic Studies				
	Major	**Advised**	**Registered**	**Period**
	B. Sh - Fundamentals of Religion	188	188	188
	B. Sh - Jurispudence and its Fundamentals	163	163	163
	B.A in Shari'a / Islamic Shari'a	6	6	6
	B.A. in Shari'a / Fundamentals of Jurispruden	0	0	0
	M. in Exegesis & Hadith	30	30	30
	M.A. in Jurispudence and its Fundamentals	35	35	35
	Total	**422**	**422**	**422**
Faculty: Special Study Program				
	Major	**Advised**	**Registered**	**Period**
	ND - Non Degree Program	9	9	9
	Non Degree Program-GS	1	1	1
	Total	**10**	**10**	**10**
Total		**5935**	**5935**	**5935**

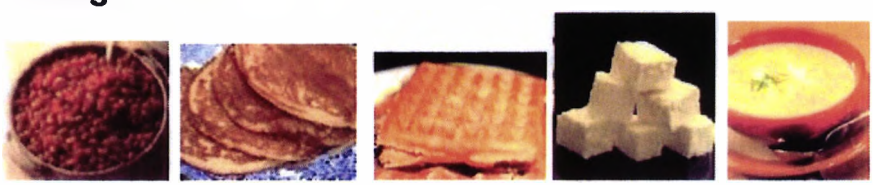
APPENDIX Q – Calcium Food Pictures

Calcium containing foods

50mg

75mg

150mg

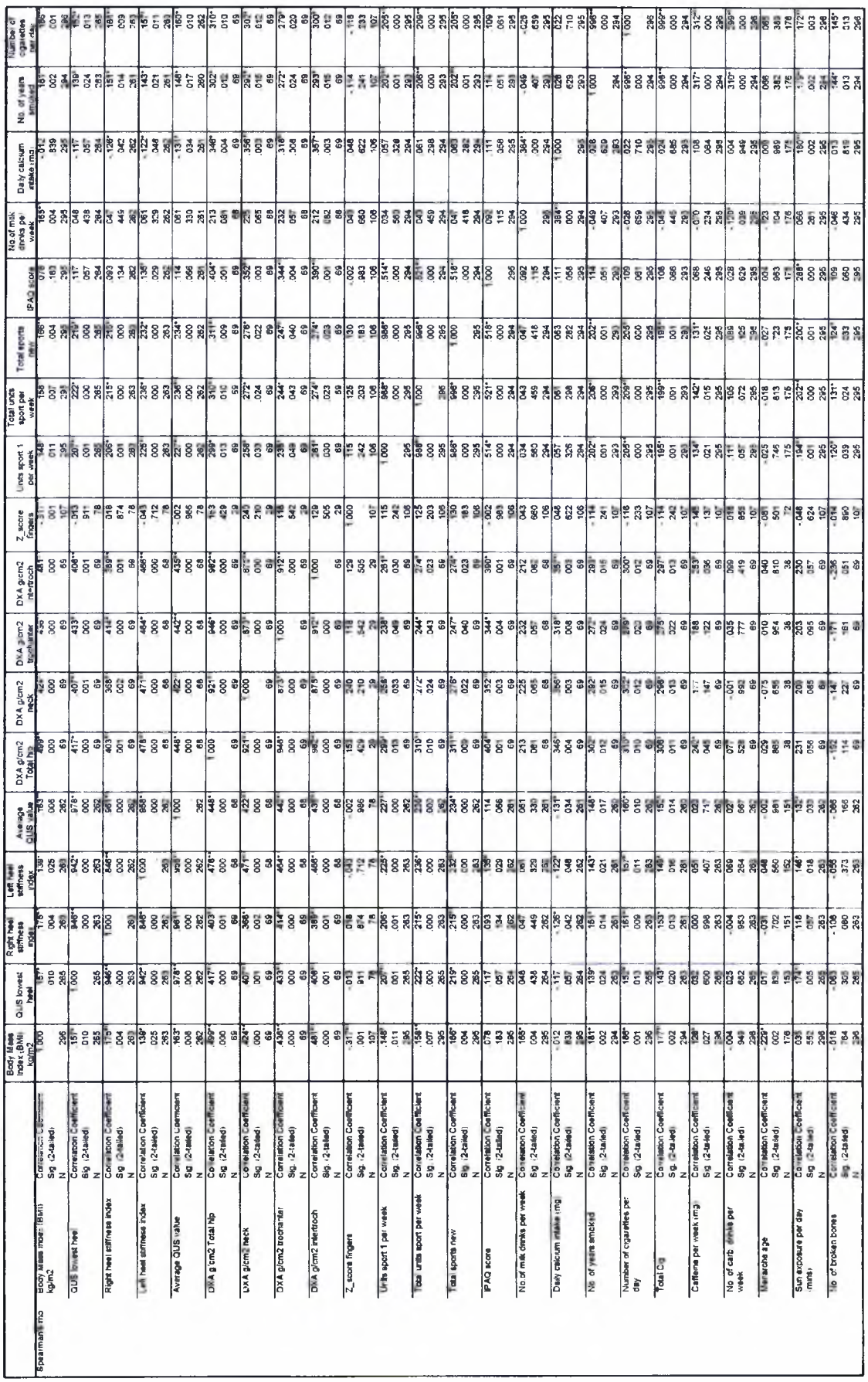


250mg

300mg

P Bell 25/FEB/2005

APPENDIX R – Correlations, All Students



End Matters

Correlations

			Total Cig	Caffeine per week (mg)	No. of carb. drinks per week	Menarche age	Sun exposure per day (mins)	No. of broken bones
Spearman's rho	Body Mass Index (BMI) kg/m2	Correlation Coefficient	.111	.128*	-.004	-.225**	.036	-.016
		Sig. (2-tailed)	.002	.027	.949	.002	.552	.764
		N	294	286	286	176	286	286
	QUS lowest heel	Correlation Coefficient	.142*	.032	.026	.017	.174**	-.063
		Sig. (2-tailed)	.020	.600	.662	.839	.005	.305
		N	283	285	285	153	285	285
	Right heel stiffness index	Correlation Coefficient	.159**	.000	-.004	-.031	.118	-.106
		Sig. (2-tailed)	.013	.998	.953	.702	.057	.080
		N	281	283	283	151	283	283
	Left heel stiffness index	Correlation Coefficient	.149*	.051	.068	.048	.146*	-.055
		Sig. (2-tailed)	.016	.407	.264	.560	.018	.373
		N	281	283	283	152	283	283
	Average QUS value	Correlation Coefficient	.162**	.023	.027	-.003	.132*	.066
		Sig. (2-tailed)	.014	.717	.657	.981	.033	.166
		N	280	282	282	151	282	282
	DXA g/cm2 Total hip	Correlation Coefficient	.306**	.242**	.077	.029	.231	-.102
		Sig. (2-tailed)	.011	.045	.228	.845	.056	.114
		N	69	69	69	38	69	69
	DXA g/cm2 neck	Correlation Coefficient	.296**	.177	-.001	-.075	.239*	-.147
		Sig. (2-tailed)	.013	.147	.992	.655	.048	.227
		N	69	69	69	36	69	69
	DXA g cm2 trochanter	Correlation Coefficient	.276*	.189	.035	.010	.203	-.171
		Sig. (2-tailed)	.022	.122	.777	.954	.095	.161
		N	69	69	69	36	69	69
	DXA g/cm2 intertouch	Correlation Coefficient	.299**	.253*	.099	.040	.230*	-.238*
		Sig. (2-tailed)	.013	.036	.419	.810	.057	.051
		N	69	69	69	36	69	69
	Z_score fingers	Correlation Coefficient	-.114	-.145	.018	-.081	-.048	-.014
		Sig. (2-tailed)	.342	.137	.855	.501	.624	.890
		N	107	107	107	72	107	107
	Units sport 1 per week	Correlation Coefficient	.195*	.134*	.111	-.025	.194*	.120*
		Sig. (2-tailed)	.001	.021	.057	.746	.001	.039
		N	293	285	293	175	295	295
	Total units sport per week	Correlation Coefficient	.159**	.142*	.106	-.018	.202**	.131*
		Sig. (2-tailed)	.001	.015	.072	.813	.000	.024
		N	293	285	293	175	295	295
	Total sports nav	Correlation Coefficient	.195**	.131*	.089	-.027	.200**	.124*
		Sig. (2-tailed)	.001	.025	.125	.723	.001	.033
		N	293	285	293	175	295	295
	IPAQ score	Correlation Coefficient	.108	.068	.028	.004	.268**	.109
		Sig. (2-tailed)	.066	.246	.629	.963	.000	.063
		N	293	285	285	175	285	285
	No. of milk drinks per week	Correlation Coefficient	-.045	-.070	-.120*	-.123	.066	-.046
		Sig. (2-tailed)	.445	.234	.039	.104	.261	.434
		N	293	285	285	176	295	295
	Daily calcium intake (mg)	Correlation Coefficient	.023	.105	.004	.053	.180**	.013
		Sig. (2-tailed)	.688	.084	.943	.969	.002	.819
		N	293	285	285	175	295	295
	No. of pets smoked	Correlation Coefficient	.998**	.311**	.310**	.086	.179**	.142*
		Sig. (2-tailed)	.000	.000	.000	.348	.002	.013
		N	294	294	294	176	294	294
	Number of cigarettes per day	Correlation Coefficient	.999**	.312**	.299**	.065	.172**	.142*
		Sig. (2-tailed)	.000	.000	.000	.388	.003	.013
		N	294	294	294	176	294	294
	Total Cig	Correlation Coefficient	1.000	.324**	.315**	.066	.176**	.142*
		Sig. (2-tailed)	.	.000	.000	.386	.002	.015
		N	294	294	294	176	294	294
	Caffeine per week (mg)	Correlation Coefficient	.324**	1.000	.504**	.093	.162**	.134*
		Sig. (2-tailed)	.000	.	.000	.221	.005	.021
		N	294	294	294	176	294	294
	No. of carb. drinks per week	Correlation Coefficient	.315**	.504**	1.000	.070	.139**	.133*
		Sig. (2-tailed)	.000	.000	.	.353	.016	.022
		N	294	294	294	176	294	294
	Menarche age	Correlation Coefficient	.066	.093	.070	1.000	.128*	-.154*
		Sig. (2-tailed)	.386	.221	.353	.	.093	.473
		N	176	176	176	176	176	176
	Sun exposure per day (mins)	Correlation Coefficient	.176**	.162**	.139**	.127	1.000	.116*
		Sig. (2-tailed)	.002	.005	.016	.093	.	.042
		N	294	294	294	176	296	296
	No. of broken bones	Correlation Coefficient	.142*	.134*	.133*	.064	.116*	1.000
		Sig. (2-tailed)	.015	.021	.022	.473	.042	.
		N	294	294	294	176	296	296

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

APPENDIX S – Correlations, Males

			OUS lowest heel	Right heel stiffness index	Right heel T-score	Left heel stiffness index	Left heel T	DXA g/cm2 Total hip	DXA T-score Total hip	DXA g/cm2 neck	DXA T-score neck	DXA g/cm2 trochanter	DXA T-score trochanter	DXA g/cm2 intertroch
Spearman's rho	OUS lowest heel	Correlation Coefficient	1.000	.952**		.950**		.506**	.512**	.546**	.557**	.630**	.626**	.494**
		Sig. (2-tailed)		.000		.000		.004	.003	.001	.001	.000	.000	.005
		N	112	112	0	111	0	31	31	31	31	31	31	31
	Right heel stiffness index	Correlation Coefficient	.952**	1.000		.864**		.484**	.499**	.484**	.495**	.601**	.598**	.485**
		Sig. (2-tailed)	.000			.000		.005	.004	.006	.005	.000	.000	.006
		N	112	112	0	111	0	31	31	31	31	31	31	31
	Right heel T-score	Correlation Coefficient												
		Sig. (2-tailed)												
		N	0	0	0	0	0	0	0	0	0	0	0	0
	Left heel stiffness index	Correlation Coefficient	.950**	.864**		1.000		.588**	.587**	.636**	.645**	.647**	.640**	.556**
		Sig. (2-tailed)	.000	.000				.001	.001	.000	.000	.000	.000	.001
		N	111	111	0	111	0	30	30	30	30	30	30	30
	Left heel T-score	Correlation Coefficient												
		Sig. (2-tailed)												
		N	0	0	0	0	0	0	0	0	0	0	0	0
	DXA g/cm2 Total hip	Correlation Coefficient	.506**	.484**		.588**		1.000	.997**	.831**	.834**	.932**	.932**	.973**
		Sig. (2-tailed)	.004	.005		.001			.000	.000	.000	.000	.000	.000
		N	31	31	0	30	0	31	31	31	31	31	31	31
	DXA T-score Total hip	Correlation Coefficient	.512**	.499**		.587**		.997**	1.000	.826**	.828**	.930**	.931**	.978**
		Sig. (2-tailed)	.003	.004		.001		.000		.000	.000	.000	.000	.000
		N	31	31	0	30	0	31	31	31	31	31	31	31
	DXA g/cm2 neck	Correlation Coefficient	.546**	.484**		.636**		.831**	.826**	1.000	.999**	.841**	.839**	.754**
		Sig. (2-tailed)	.001	.006		.000		.000	.000		.000	.000	.000	.000
		N	31	31	0	30	0	31	31	31	31	31	31	31
	DXA T-score neck	Correlation Coefficient	.557**	.495**		.645**		.834**	.828**	.999**	1.000	.842**	.840**	.756**
		Sig. (2-tailed)	.001	.005		.000		.000	.000	.000		.000	.000	.000
		N	31	31	0	30	0	31	31	31	31	31	31	31
	DXA g/cm2 trochanter	Correlation Coefficient	.630**	.601**		.647**		.932**	.930**	.841**	.842**	1.000	.998**	.874**
		Sig. (2-tailed)	.000	.000		.000		.000	.000	.000	.000		.000	.000
		N	31	31	0	30	0	31	31	31	31	31	31	31
	DXA T-score trochanter	Correlation Coefficient	.626**	.598**		.640**		.932**	.931**	.839**	.840**	.998**	1.000	.877**
		Sig. (2-tailed)	.000	.000		.000		.000	.000	.000	.000	.000		.000
		N	31	31	0	30	0	31	31	31	31	31	31	31
	DXA g/cm2 intertroch	Correlation Coefficient	.494**	.485**		.556**		.973**	.978**	.754**	.756**	.874**	.877**	1.000
		Sig. (2-tailed)	.005	.006		.001		.000	.000	.000	.000	.000	.000	
		N	31	31	0	30	0	31	31	31	31	31	31	31
	DXA T-score intertroch	Correlation Coefficient	.498*	.490**		.581**		.975**	.980**	.755**	.757**	.879**	.883**	.999**
		Sig. (2-tailed)	.004	.005		.001		.000	.000	.000	.000	.000	.000	.000
		N	31	31	0	30	0	31	31	31	31	31	31	31
	DXA result	Correlation Coefficient	.198	.220		.155		.428*	.427*	.323	.323	.382*	.375*	.411*
		Sig. (2-tailed)	.285	.234		.415		.017	.017	.076	.076	.034	.038	.022
		N	31	31	0	30	0	31	31	31	31	31	31	31
	Z_score fingers	Correlation Coefficient	.076	.041		.123		.190	.204	.238	.238	.108	.108	.214
		Sig. (2-tailed)	.700	.837		.533		.651	.629	.570	.570	.799	.799	.610
		N	28	28	0	28	0	8	8	8	8	8	8	8
	Age (years)	Correlation Coefficient	-.170	.168		.181		-.110	-.083	-.124	-.135	-.111	-.086	-.046
		Sig. (2-tailed)	.073	.077		.057		.555	.659	.506	.470	.551	.644	.805
		N	112	112	0	111	0	31	31	31	31	31	31	31
	Body Mass Index (BMI) kg/m2	Correlation Coefficient	-.059	.008		-.086		.264	.298	.130	.117	.214	.206	.278
		Sig. (2-tailed)	.536	.950		.367		.121	.104	.485	.531	.248	.268	.130
		N	112	112	0	111	0	31	31	31	31	31	31	31
	BMI category	Correlation Coefficient	-.125	.068		-.144		.243	.261	.087	.080	.182	.158	.253
		Sig. (2-tailed)	.190	.473		.133		.187	.155	.602	.669	.382	.397	.170
		N	112	112	0	111	0	31	31	31	31	31	31	31
	Units sport 1 per week	Correlation Coefficient	.121	.131		.127		.034	-.025	.124	-.123	-.137	-.137	-.054
		Sig. (2-tailed)	.205	.169		.184		.856	.892	.505	.511	.461	.461	.773
		N	112	112	0	111	0	31	31	31	31	31	31	31
	Total units sport per week	Correlation Coefficient	.130	.124		.132		-.021	-.012	-.090	-.095	-.125	-.130	-.033
		Sig. (2-tailed)	.171	.193		.167		.912	.950	.629	.613	.504	.487	.860
		N	112	112	0	111	0	31	31	31	31	31	31	31
	Total sports new	Correlation Coefficient	.132	.131		.132		.038	.041	-.041	-.044	-.077	-.080	.022
		Sig. (2-tailed)	.166	.170		.167		.871	.828	.827	.816	.682	.669	.908
		N	112	112	0	111	0	31	31	31	31	31	31	31
	IPAQ score	Correlation Coefficient	.101	.089		.087		.130	.154	.073	.056	.189	.174	.151
		Sig. (2-tailed)	.292	.467		.366		.487	.409	.698	.755	.363	.349	.417
		N	112	112	0	111	0	31	31	31	31	31	31	31
	Activity code	Correlation Coefficient	.108	.090		.069		.082	.082	.082	.048	.050	.048	.076
		Sig. (2-tailed)	.258	.346		.471		.781	.662	.740	.807	.790	.797	.683
		N	112	112	0	111	0	31	31	31	31	31	31	31
	No of milk drinks per week	Correlation Coefficient	.085	.062		.111		-.152	-.134	-.088	-.108	.221	-.216	-.107
		Sig. (2-tailed)	.373	.515		.249		.422	.481	.643	.565	.241	.252	.575
		N	111	111	0	110	0	30	30	30	30	30	30	30
	No of milk drinks per week (Banded)	Correlation Coefficient	.129	.111		.145		-.080	-.067	.051	.028	-.077	-.079	-.120
		Sig. (2-tailed)	.175	.245		.128		.669	.783	.785	.875	.682	.675	.522
		N	112	112	0	111	0	31	31	31	31	31	31	31
	Daily calcium intake (mg)	Correlation Coefficient	.165	.144		.185		.253	.253	.218	.201	.228	.215	.266
		Sig. (2-tailed)	.082	.131		.052		.170	.169	.256	.278	.221	.246	.148
		N	112	112	0	111	0	31	31	31	31	31	31	31
	Calcium intake level	Correlation Coefficient	-.124	-.107		-.151		.287	.284	.208	.208	.235	.219	.300
		Sig. (2-tailed)	.194	.263		.113		.118	.122	.261	.266	.203	.236	.101
		N	112	112	0	111	0	31	31	31	31	31	31	31
	Rescaled calcium	Correlation Coefficient	.165	.144		.185		.253	.253	.218	.201	.228	.215	.266
		Sig. (2-tailed)	.082	.131		.052		.170	.169	.256	.278	.221	.246	.148
		N	112	112	0	111	0	31	31	31	31	31	31	31
	Ever smoked	Correlation Coefficient	.086	.122		.112		.008	.027	.056	.058	-.008	.004	.015
		Sig. (2-tailed)	.312	.200		.243		.967	.885	.789	.757	.967	.984	.934
		N	112	112	0	111	0	31	31	31	31	31	31	31
	No. of years smoked	Correlation Coefficient	.046	.086		.059		-.038	-.021	.000	.008	-.025	-.013	-.038
		Sig. (2-tailed)	.639	.372		.544		.838	.911	.999	.975	.896	.946	.838
		N	110	110	0	109	0	31	31	31	31	31	31	31
	Number of cigarettes per day	Correlation Coefficient	.082	.106		.100		.008	.022	.045	.053	.009	.022	.002
		Sig. (2-tailed)	.388	.264		.294		.965	.906	.806	.778	.962	.907	.991
		N	112	112	0	111	0	31	31	31	31	31	31	31
	Total Cig	Correlation Coefficient	.071	.100		.088		-.013	.002	.022	.029	-.009	.003	-.017
		Sig. (2-tailed)	.463	.298		.364		.944	.991	.905	.876	.961	.987	.930
		N	110	110	0	109	0	31	31	31	31	31	31	31
	Caffeine per week (mg)	Correlation Coefficient	-.048	.063		.024		.202	.171	.164	.172	.149	.165	.189
		Sig. (2-tailed)	.618	.509		.800		.277	.357	.378	.354	.422	.376	.309
		N	112	112	0	111	0	31	31	31	31	31	31	31
	Caffeine per week (mg) (Banded)	Correlation Coefficient	-.045	.044		.015		.125	.088	.116	.125	.033	.046	.145
		Sig. (2-tailed)	.641	.644		.878		.502	.636	.540	.502	.861	.804	.436
		N	112	112	0	111	0	31	31	31	31	31	31	31
	No. of carb. drinks per week	Correlation Coefficient	-.003	.010		.015		.076	.082	-.064	-.045	.089	.070	.110
		Sig. (2-tailed)	.977	.917		.877		.686	.741	.757	.806	.710	.708	.554
		N	112	112	0	111	0	31	31	31	31	31	31	31
	carbonated drinks	Correlation Coefficient	-.057	.048		-.028		.138	.120	-.084	.012	.137	.134	.118
		Sig. (2-tailed)	.551	.617		.770		.460	.521	.983	.951	.462	.473	.526
		N	112	112	0	111	0	31	31	31	31	31	31	31
	Menarche age	Correlation Coefficient												
		Sig. (2-tailed)												
		N	0	0	0	0	0	0	0	0	0	0	0	0
	Menstrual regularity	Correlation Coefficient												
		Sig. (2-tailed)												
		N	0	0	0	0	0	0	0	0	0	0	0	0
	Sun exposure per day (mins)	Correlation Coefficient	.076	.061		.014		-.017	.009	.053	.042	.073	.072	-.010
		Sig. (2-tailed)	.427	.521		.883		.927	.963	.778	.820	.697	.701	.958
		N	112	112	0	111	0	31	31	31	31	31	31	31
	No. of broken bones	Correlation Coefficient	.164	.205*		.161		-.204	-.221	-.167	-.176	-.079	-.079	-.291
		Sig. (2-tailed)	.083	.030		.092		.271	.233	.368	.343	.672	.675	.112
		N	112	112	0	111	0	31	31	31	31	31	31	31

			DXA T-score intertroch	DXA result	Z_score fingers	Age (years)	Body Mass Index (BMI) kg/m2	BMI category	Units sport 1 per week	Total units sport per week	Total sports new	IPAQ score	Activity code	No of milk drinks per week
Spearman's rho	QUS lowest heel	Correlation Coefficient	.488**	.188	.076	-.170	-.088	-.125	.121	.130	.132	.161	.166	.085
		Sig. (2-tailed)	.004	.285	.700	.073	.536	.190	.206	.171	.166	.292	.258	.373
		N	31	31	28	112	112	112	112	112	112	112	112	111
	Right heel stiffness index	Correlation Coefficient	.480**	.276	.041	-.158	.006	-.068	.131	.124	.131	.099	.090	.052
		Sig. (2-tailed)	.005	.234	.837	.077	.950	.473	.169	.193	.170	.467	.346	.515
		N	31	31	28	112	112	112	112	112	112	112	112	111
	Right heel T-score	Correlation Coefficient												
		Sig. (2-tailed)												
		N	0	0	0	0	0	0	0	0	0	0	0	0
	Left heel stiffness index	Correlation Coefficient	.561**	.156	.123	-.181	-.066	-.144	.127	.132	.132	.087	.069	.111
		Sig. (2-tailed)	.001	.416	.533	.057	.367	.133	.184	.167	.167	.366	.471	.249
		N	30	30	28	111	111	111	111	111	111	111	111	110
	Left heel T score	Correlation Coefficient												
		Sig. (2-tailed)												
		N	0	0	0	0	0	0	0	0	0	0	0	0
	DXA g/cm2 Total hip	Correlation Coefficient	.975**	.426*	.190	-.110	.284	.243	-.034	-.021	.030	.130	.052	-.152
		Sig. (2-tailed)	.000	.017	.651	.555	.121	.187	.856	.912	.871	.487	.781	.422
		N	31	31	8	31	31	31	31	31	31	31	31	30
	DXA T-score Total hip	Correlation Coefficient	.960**	.427*	.204	-.083	.298	.261	-.025	-.012	.041	.154	.082	-.134
		Sig. (2-tailed)	.000	.017	.628	.659	.104	.155	.892	.950	.828	.409	.662	.481
		N	31	31	8	31	31	31	31	31	31	31	31	30
	DXA g/cm2 neck	Correlation Coefficient	.755**	.323	.238	-.124	.130	.097	-.124	-.090	-.041	.073	.062	.068
		Sig. (2-tailed)	.000	.076	.570	.508	.485	.602	.505	.629	.827	.696	.740	.643
		N	31	31	8	31	31	31	31	31	31	31	31	30
	DXA T-score neck	Correlation Coefficient	.757**	.323	.238	-.135	.117	.080	-.123	-.085	-.044	.058	.046	-.106
		Sig. (2-tailed)	.000	.076	.570	.470	.531	.689	.511	.613	.816	.755	.807	.565
		N	31	31	8	31	31	31	31	31	31	31	31	30
	DXA g/cm2 trochanter	Correlation Coefficient	.879**	.382*	.108	-.111	.214	.162	-.137	-.125	-.077	.169	.050	-.221
		Sig. (2-tailed)	.000	.034	.799	.561	.248	.382	.461	.504	.682	.363	.790	.241
		N	31	31	8	31	31	31	31	31	31	31	31	30
	DXA T score trochanter	Correlation Coefficient	.883**	.375*	.108	-.086	.206	.158	-.137	-.130	-.080	.174	.048	-.216
		Sig. (2-tailed)	.000	.038	.799	.644	.266	.397	.461	.487	.669	.349	.797	.252
		N	31	31	8	31	31	31	31	31	31	31	31	30
	DXA g/cm2 intertroch	Correlation Coefficient	.898**	.411*	.214	-.046	.276	.253	-.054	-.033	.022	.151	.076	-.107
		Sig. (2-tailed)	.000	.022	.610	.805	.130	.170	.773	.860	.908	.417	.683	.575
		N	31	31	8	31	31	31	31	31	31	31	31	30
	DXA T-score intertroch	Correlation Coefficient	1.000	.411*	.214	-.048	.285	.258	-.057	-.037	.018	.156	.080	-.108
		Sig. (2-tailed)		.021	.610	.796	.121	.162	.761	.845	.922	.401	.669	.569
		N	31	31	8	31	31	31	31	31	31	31	31	30
	DXA result	Correlation Coefficient	.411*	1.000		-.396**	.387*	.264	-.022	.037	.067	.132	.269	-.196
		Sig. (2-tailed)	.021			.027	.042	.152	.905	.842	.719	.479	.143	.296
		N	31	31	8	31	31	31	31	31	31	31	31	30
	Z_score fingers	Correlation Coefficient	.214		1.000	-.009	-.328	-.358**	.081	.054	.044	-.076	.109	.177
		Sig. (2-tailed)	.610			.958	.054	.035	.993	.759	.800	.695	.532	.317
		N	8	8	35	35	35	35	35	35	35	35	35	34
	Age (years)	Correlation Coefficient	-.048	-.396*	-.009	1.000	.195*	.156	-.079	-.083	-.089	-.011	-.032	.059
		Sig. (2-tailed)	.796	.027	.958		.033	.066	.392	.376	.333	.908	.730	.525
		N	31	31	35	120	120	120	120	120	120	120	120	119
	Body Mass Index (BMI) kg/m2	Correlation Coefficient	.285	.387*	-.329	.195*	1.000	.941**	.024	.038	.052	.007	.060	.143
		Sig. (2-tailed)	.121	.042	.054	.033		.000	.794	.674	.573	.938	.514	.120
		N	31	31	35	120	120	120	120	120	120	120	120	119
	BMI category	Correlation Coefficient	.258	.284	-.358*	.156	.941**	1.000	-.008	.009	.023	-.016	.023	.118
		Sig. (2-tailed)	.162	.152	.035	.088	.000		.955	.921	.803	.860	.800	.199
		N	31	31	35	120	120	120	120	120	120	120	120	119
	Units sport 1 per week	Correlation Coefficient	-.067	-.022	.001	-.079	.024	-.008	1.000	.985**	.985**	.492**	.496**	-.014
		Sig. (2-tailed)	.761	.905	.993	.392	.794	.955		.000	.000	.000	.000	.876
		N	31	31	35	120	120	120	120	120	120	120	120	119
	Total units sport per week	Correlation Coefficient	-.037	.037	.064	-.083	.038	.009	.988**	1.000	.988**	.511**	.543**	.035
		Sig. (2-tailed)	.845	.842	.759	.370	.674	.921	.000		.000	.000	.000	.709
		N	31	31	35	120	120	120	120	120	120	120	120	119
	Total sports new	Correlation Coefficient	.018	.067	.044	-.089	.052	.023	.985**	.990**	1.000	.508**	.534**	.041
		Sig. (2-tailed)	.922	.719	.800	.333	.573	.803	.000	.000		.000	.000	.655
		N	31	31	35	120	120	120	120	120	120	120	120	119
	IPAQ score	Correlation Coefficient	.156	.132	-.076	-.011	.007	-.016	.492**	.511**	.508**	1.000	.862**	.072
		Sig. (2-tailed)	.401	.479	.665	.908	.938	.860	.000	.000	.000		.000	.438
		N	31	31	35	120	120	120	120	120	120	120	120	119
	Activity code	Correlation Coefficient	.060	.269	.109	-.032	.060	.023	.496**	.543**	.534**	.862**	1.000	.086
		Sig. (2-tailed)	.668	.143	.532	.730	.514	.800	.000	.000	.000	.000		.299
		N	31	31	35	120	120	120	120	120	120	120	120	119
	No of milk drinks per week	Correlation Coefficient	-.108	-.196	.177	.089	.143	.118	-.014	.035	.041	.072	.086	1.000
		Sig. (2-tailed)	.568	.298	.317	.525	.120	.199	.876	.709	.655	.438	.299	
		N	30	30	34	119	119	119	119	119	119	119	119	119
	No of milk drinks per week (Banded)	Correlation Coefficient	-.112	-.097	.113	.012	.212*	.205*	-.020	.004	.009	.047	.109	.886**
		Sig. (2-tailed)	.548	.602	.520	.894	.020	.025	.826	.970	.924	.608	.234	.000
		N	31	31	35	120	120	120	120	120	120	120	120	119
	Daily calcium intake (mg)	Correlation Coefficient	.260	.081	.148	-.019	.031	.046	-.044	-.018	.065	.101	.130	.342**
		Sig. (2-tailed)	.128	.666	.397	.834	.737	.625	.636	.846	.956	.272	.157	.000
		N	31	31	35	120	120	120	120	120	120	120	120	119
	Calcium intake level	Correlation Coefficient	.310	.126	.192	-.034	.058	.073	-.027	.011	.024	.058	.110	.282**
		Sig. (2-tailed)	.090	.500	.269	.715	.529	.426	.767	.905	.796	.531	.232	.004
		N	31	31	35	120	120	120	120	120	120	120	120	119
	Rounded calcium	Correlation Coefficient	.260	.081	-.148	-.019	.031	.045	-.044	-.018	.065	.101	.130	.342**
		Sig. (2-tailed)	.128	.666	.397	.834	.737	.625	.636	.846	.956	.272	.157	.000
		N	31	31	35	120	120	120	120	120	120	120	120	119
	Ever smoked	Correlation Coefficient	.019	.181	-.237	.116	.068	.081	-.017	-.025	-.025	-.064	-.057	-.076
		Sig. (2-tailed)	.918	.329	.170	.205	.459	.321	.853	.783	.783	.485	.538	.412
		N	31	31	35	120	120	120	120	120	120	120	120	119
	No of years smoked	Correlation Coefficient	-.034	.177	-.204	.122	.068	.089	-.037	-.041	-.042	-.062	-.058	-.133
		Sig. (2-tailed)	.856	.341	.241	.188	.461	.339	.689	.658	.649	.508	.523	.154
		N	31	31	35	118	118	118	118	118	118	118	118	117
	Number of cigarettes per day	Correlation Coefficient	.008	.177	-.218	.122	.051	.084	-.062	-.064	-.067	-.078	-.080	-.095
		Sig. (2-tailed)	.673	.341	.207	.184	.579	.487	.503	.466	.468	.447	.328	.305
		N	31	31	35	120	120	120	120	120	120	120	120	119
	Total Cig	Correlation Coefficient	-.012	.177	-.204	.116	.054	.087	-.067	-.069	-.070	-.078	-.091	-.121
		Sig. (2-tailed)	.947	.341	.238	.208	.564	.469	.472	.459	.448	.416	.326	.193
		N	31	31	35	118	118	118	118	118	118	118	118	117
	Caffeine per week (mg)	Correlation Coefficient	.191	-.183	-.068	.028	.007	.030	-.051	-.062	-.078	-.016	-.118	-.088
		Sig. (2-tailed)	.303	.582	.813	.758	.936	.746	.581	.504	.448	.858	.200	.350
		N	31	31	35	120	120	120	120	120	120	120	120	119
	Caffeine per week (mg) (Banded)	Correlation Coefficient	.141	-.230	-.034	.064	.000	.029	-.085	-.098	-.101	-.071	-.169	-.077
		Sig. (2-tailed)	.450	.214	.845	.485	.997	.752	.357	.295	.274	.442	.066	.407
		N	31	31	35	120	120	120	120	120	120	120	120	119
	No of carb drinks per week	Correlation Coefficient	.118	-.125	.010	-.115	-.133	-.116	-.174	-.206*	-.236**	-.241**	-.206*	-.189
		Sig. (2-tailed)	.526	.502	.954	.213	.149	.206	.058	.024	.013	.008	.002	.066
		N	31	31	35	120	120	120	120	120	120	120	120	119
	carbonated drinks	Correlation Coefficient	.124	-.034	-.054	-.161	-.134	-.114	-.167	-.208*	-.220*	-.256**	-.278**	-.202*
		Sig. (2-tailed)	.507	.856	.756	.080	.144	.215	.068	.023	.016	.005	.002	.026
		N	31	31	35	120	120	120	120	120	120	120	120	119
	Menarche age	Correlation Coefficient												
		Sig. (2-tailed)												
		N	0	0	0	0	0	0	0	0	0	0	0	0
	Menstrual regularity	Correlation Coefficient												
		Sig. (2-tailed)												
		N	0	0	0	0	0	0	0	0	0	0	0	0
	Sun exposure per day (mins)	Correlation Coefficient	.002	.022	.087	-.087	-.182*	-.148	.020	.009	.030	.071	.070	-.016
		Sig. (2-tailed)	.991	.905	.970	.484	.047	.128	.831	.918	.743	.443	.448	.863
		N	31	31	35	120	120	120	120	120	120	120	120	119
	No of broken bones	Correlation Coefficient	-.279	-.102	-.078	-.058	-.026	-.024	.159	.162	.145	.089	.139	-.044
		Sig. (2-tailed)	.128	.587	.658	.530	.779	.794	.084	.076	.114	.283	.131	.635
		N	31	31	35	120	120	120	120	120	120	120	120	119

			No of milk drinks per week (Banded)	Daily calcium intake (mg)	Calcium intake level	Rescaled calcium	Ever smoked	No. of years smoked	Number of cigarettes per day	Total Cig	Caffeine per week (mg)	Caffeine per week (mg) (Banded)	No. of carb drinks per week
Spearman's rho	QUS lowest heal	Correlation Coefficient	129	-.165	-.124	-.165	.088	.048	.082	.071	-.048	-.045	-.003
		Sig. (2-tailed)	175	.082	.194	.082	.312	.630	.388	.463	.618	.641	.977
		N	112	112	112	112	112	110	112	110	112	112	112
	Right heel stiffness index	Correlation Coefficient	111	-.144	-.107	-.144	.122	.088	.166	.100	-.083	-.044	.010
		Sig. (2-tailed)	245	.131	.263	.131	.200	.372	.264	.298	.509	.644	.917
		N	112	112	112	112	112	110	112	110	112	112	112
	Right heel T-score	Correlation Coefficient	.	.	.	.	.	.	.	.	.	.	.
		Sig. (2-tailed)	.	.	.	.	.	.	.	.	.	.	.
		N	0	0	0	0	0	0	0	0	0	0	0
	Left heel stiffness index	Correlation Coefficient	.145	-.185	-.151	-.185	.112	.059	.100	.088	.024	.015	.015
		Sig. (2-tailed)	.129	.052	.113	.052	.243	.544	.294	.364	.800	.876	.877
		N	111	111	111	111	111	109	111	109	111	111	111
	Left heel T-score	Correlation Coefficient	.	.	.	.	.	.	.	.	.	.	.
		Sig. (2-tailed)	.	.	.	.	.	.	.	.	.	.	.
		N	0	0	0	0	0	0	0	0	0	0	0
	DXA g/cm2 Total hip	Correlation Coefficient	-.080	.253	.287	.253	.008	-.030	.008	-.013	.262	.125	.076
		Sig. (2-tailed)	.669	.178	.118	.170	.967	.838	.965	.944	.277	.502	.686
		N	31	31	31	31	31	31	31	31	31	31	31
	DXA T-score Total hip	Correlation Coefficient	-.057	.253	.284	.253	-.027	-.021	.022	.002	.171	.098	.062
		Sig. (2-tailed)	.763	.169	.122	.169	.885	.911	.908	.991	.357	.600	.741
		N	31	31	31	31	31	31	31	31	31	31	31
	DXA g/cm2 neck	Correlation Coefficient	.051	.210	.208	.210	.050	.000	.045	.022	.164	.115	-.056
		Sig. (2-tailed)	.785	.256	.261	.256	.789	.999	.808	.905	.378	.540	.757
		N	31	31	31	31	31	31	31	31	31	31	31
	DXA T-score neck	Correlation Coefficient	.029	.201	.208	.201	.058	.008	.053	.029	.172	.125	-.045
		Sig. (2-tailed)	.875	.279	.266	.279	.757	.973	.778	.876	.354	.502	.808
		N	31	31	31	31	31	31	31	31	31	31	31
	DXA g/cm2 trochanter	Correlation Coefficient	-.077	.226	.235	.226	-.008	-.025	.009	.009	.149	.033	.089
		Sig. (2-tailed)	.682	.221	.203	.221	.967	.896	.962	.961	.422	.861	.710
		N	31	31	31	31	31	31	31	31	31	31	31
	DXA T-score trochanter	Correlation Coefficient	-.070	.215	.219	.215	.004	-.013	.022	.063	.165	.046	.070
		Sig. (2-tailed)	.675	.246	.236	.246	.984	.946	.907	.987	.376	.804	.708
		N	31	31	31	31	31	31	31	31	31	31	31
	DXA g/cm2 Intertroch	Correlation Coefficient	-.120	.288	.300	.288	.015	-.038	.002	-.017	.189	.145	.110
		Sig. (2-tailed)	.522	.148	.101	.148	.934	.838	.991	.930	.309	.436	.554
		N	31	31	31	31	31	31	31	31	31	31	31
	DXA T-score intertroch	Correlation Coefficient	-.112	.260	.310	.260	.019	.034	.008	-.012	.191	.141	.116
		Sig. (2-tailed)	.548	.128	.090	.128	.918	.856	.973	.947	.303	.450	.535
		N	31	31	31	31	31	31	31	31	31	31	31
	DXA result	Correlation Coefficient	-.067	.081	.126	.081	.181	.177	.177	.177	-.103	-.230	-.125
		Sig. (2-tailed)	.602	.666	.500	.666	.329	.341	.341	.341	.582	.214	.502
		N	31	31	31	31	31	31	31	31	31	31	31
	Z_score fingers	Correlation Coefficient	.113	.148	-.192	-.148	-.237	-.204	-.219	-.204	.088	-.034	.010
		Sig. (2-tailed)	.520	.397	.269	.397	.170	.241	.207	.239	.613	.845	.954
		N	35	35	35	35	35	35	35	35	35	35	35
	Age (years)	Correlation Coefficient	.012	-.019	-.034	-.019	.116	.122	.122	.116	.028	.064	-.115
		Sig. (2-tailed)	.894	.834	.715	.834	.205	.189	.184	.209	.758	.485	.213
		N	120	120	120	120	120	118	120	118	120	120	120
	Body Mass Index (BMI) kg/m2	Correlation Coefficient	.212*	.031	.058	.031	.068	.069	.051	.054	.007	.000	-.133
		Sig. (2-tailed)	.020	.737	.529	.737	.459	.461	.579	.564	.936	.997	.149
		N	120	120	120	120	120	118	120	118	120	120	120
	BMI category	Correlation Coefficient	.205*	.045	.073	.045	.081	.089	.064	.067	.030	.029	-.116
		Sig. (2-tailed)	.025	.625	.426	.625	.321	.339	.487	.469	.746	.752	.206
		N	120	120	120	120	120	118	120	118	120	120	120
	Units sport 1 per week	Correlation Coefficient	-.020	-.044	-.027	-.044	-.017	.037	-.062	-.067	-.051	-.065	-.174
		Sig. (2-tailed)	.828	.636	.767	.636	.853	.689	.503	.472	.581	.357	.058
		N	120	120	120	120	120	118	120	118	120	120	120
	Total units sport per week	Correlation Coefficient	.004	-.018	.011	-.018	-.025	-.041	-.064	-.069	-.082	-.095	-.206*
		Sig. (2-tailed)	.970	.846	.905	.846	.783	.658	.486	.459	.504	.295	.024
		N	120	120	120	120	120	118	120	118	120	120	120
	Total sports new	Correlation Coefficient	.009	.005	.024	.005	-.025	-.042	-.067	-.070	.070	-.101	-.226*
		Sig. (2-tailed)	.924	.956	.798	.956	.783	.649	.466	.448	.448	.274	.013
		N	120	120	120	120	120	118	120	118	120	120	120
	IPAQ score	Correlation Coefficient	.047	.101	.058	.101	-.064	-.062	-.070	-.076	.016	-.071	-.241**
		Sig. (2-tailed)	.608	.272	.531	.272	.485	.508	.447	.416	.858	.442	.008
		N	120	120	120	120	120	118	120	118	120	120	120
	Activity code	Correlation Coefficient	.109	.130	.110	.130	-.057	-.059	.000	-.091	.118	.169	-.266**
		Sig. (2-tailed)	.234	.157	.232	.157	.539	.523	.328	.326	.200	.066	.002
		N	120	120	120	120	120	118	120	118	120	120	120
	No of milk drinks per week	Correlation Coefficient	.385**	.342**	.282**	.342**	-.076	-.133	-.095	-.121	-.086	-.077	-.169
		Sig. (2-tailed)	.000	.000	.004	.000	.412	.154	.305	.193	.350	.407	.066
		N	119	119	119	119	119	117	119	117	119	119	119
	No.of milk drinks per week (Banded)	Correlation Coefficient	1.000	.314**	.270**	.314**	-.073	-.093	-.088	-.104	-.084	-.107	-.161
		Sig. (2-tailed)	.	.000	.003	.000	.426	.315	.336	.261	.364	.248	.080
		N	120	120	120	120	120	118	120	118	120	120	120
	Daily calcium intake (mg)	Correlation Coefficient	.314**	1.000	.916**	1.000**	-.109	-.099	-.129	-.120	.068	.084	-.083
		Sig. (2-tailed)	.000	.	.000	.	.236	.286	.161	.195	.472	.364	.366
		N	120	120	120	120	120	118	120	118	120	120	120
	Calcium intake level	Correlation Coefficient	.270**	.916**	1.000	.916**	-.075	-.080	-.108	-.103	.040	.074	-.053
		Sig. (2-tailed)	.003	.000	.	.000	.418	.389	.242	.266	.664	.424	.565
		N	120	120	120	120	120	118	120	118	120	120	120
	Rescaled calcium	Correlation Coefficient	.314**	1.000**	.916**	1.000	-.109	-.099	-.129	-.120	.068	.084	-.083
		Sig. (2-tailed)	.000	.	.000	.	.236	.286	.161	.195	.472	.364	.366
		N	120	120	120	120	120	118	120	118	120	120	120
	Ever smoked	Correlation Coefficient	-.073	-.109	-.075	-.109	1.000	.982**	.956**	.981**	.323**	.228*	.282**
		Sig. (2-tailed)	.426	.236	.418	.236	.	.000	.000	.000	.000	.012	.002
		N	120	120	120	120	120	118	120	118	120	120	120
	No. of years smoked	Correlation Coefficient	-.093	-.099	-.080	-.099	.982**	1.000	.973**	.989**	.346**	.250**	.276**
		Sig. (2-tailed)	.315	.286	.389	.286	.000	.	.000	.000	.000	.006	.003
		N	118	118	118	118	118	118	118	118	118	118	118
	Number of cigarettes per day	Correlation Coefficient	-.088	-.129	-.108	-.129	.956**	.973**	1.000	.985**	.385**	.289**	.285**
		Sig. (2-tailed)	.336	.161	.242	.161	.000	.000	.	.000	.000	.003	.002
		N	120	120	120	120	120	118	120	118	120	120	120
	Total Cig	Correlation Coefficient	-.104	-.120	-.103	-.120	.981**	.989**	.985**	1.000	.371**	.278**	.296**
		Sig. (2-tailed)	.261	.195	.266	.195	.000	.000	.000	.	.000	.002	.001
		N	118	118	118	118	118	118	118	118	118	118	118
	Caffeine per week (mg)	Correlation Coefficient	-.084	.086	.040	.066	.323**	.346**	.385**	.371**	1.000	.866**	.476**
		Sig. (2-tailed)	.364	.472	.664	.472	.000	.000	.000	.000	.	.000	.000
		N	120	120	120	120	120	118	120	118	120	120	120
	Caffeine per week (mg) (Banded)	Correlation Coefficient	-.107	.084	.074	.084	.228*	.250**	.289**	.278**	.866**	1.000	.378**
		Sig. (2-tailed)	.248	.364	.424	.364	.012	.006	.003	.002	.000	.	.000
		N	120	120	120	120	120	118	120	118	120	120	120
	No. of carb. drinks per week	Correlation Coefficient	-.161	-.083	.053	-.083	.282**	.276**	.285**	.296**	.476**	.378**	1.000
		Sig. (2-tailed)	.080	.366	.565	.366	.002	.003	.002	.001	.000	.000	.
		N	120	120	120	120	120	118	120	118	120	120	120
	carbonated drinks	Correlation Coefficient	-.169	-.058	.038	.058	.248**	.253**	.252**	.266**	.449**	.342**	.915**
		Sig. (2-tailed)	.065	.526	.676	.526	.006	.006	.005	.004	.000	.000	.000
		N	120	120	120	120	120	118	120	118	120	120	120
	Menarche age	Correlation Coefficient	.	.	.	.	.	.	.	.	.	.	.
		Sig. (2-tailed)	.	.	.	.	.	.	.	.	.	.	.
		N	0	0	0	0	0	0	0	0	0	0	0
	Menstrual regularity	Correlation Coefficient	.	.	.	.	.	.	.	.	.	.	.
		Sig. (2-tailed)	.	.	.	.	.	.	.	.	.	.	.
		N	0	0	0	0	0	0	0	0	0	0	0
	Sun exposure per day (mins)	Correlation Coefficient	.121	.003	-.031	.003	-.004	.011	-.015	-.004	-.015	-.024	.040
		Sig. (2-tailed)	.187	.975	.734	.975	.961	.908	.871	.962	.869	.797	.667
		N	120	120	120	120	120	118	120	118	120	120	120
	No. of broken bones	Correlation Coefficient	.088	-.039	-.049	.039	.144	.174	.183	.165	.017	-.049	.124
		Sig. (2-tailed)	.338	.675	.592	.675	.117	.059	.076	.074	.857	.605	.177
		N	120	120	120	120	120	118	120	118	120	120	120

End Matters

			carbonated drinks	Menarche age	Menstrual regularity	Sun exposure per day (mins)	No. of broken bones
Spearman's rho	QUS lowest heel	Correlation Coefficient	-.057			.076	-.164
		Sig. (2-tailed)	.551			.427	.083
		N	112	0	0	112	112
	Right heel stiffness index	Correlation Coefficient	-.048			.081	-.205*
		Sig. (2-tailed)	.617			.521	.030
		N	112	0	0	112	112
	Right heel T-score	Correlation Coefficient					
		Sig. (2-tailed)					
		N	0	0	0	0	0
	Left heel stiffness index	Correlation Coefficient	-.028			.014	-.161
		Sig. (2-tailed)	.770			.883	.092
		N	111	0	0	111	111
	Left heel T score	Correlation Coefficient					
		Sig. (2-tailed)					
		N	0	0	0	0	0
	DXA g/cm2 Total hip	Correlation Coefficient	.138			-.017	-.204
		Sig. (2-tailed)	.460			.927	.271
		N	31	0	0	31	31
	DXA T score Total hip	Correlation Coefficient	.120			.009	-.221
		Sig. (2-tailed)	.521			.963	.233
		N	31	0	0	31	31
	DXA g/cm2 neck	Correlation Coefficient	.004			.053	-.187
		Sig. (2-tailed)	.983			.778	.368
		N	31	0	0	31	31
	DXA T-score neck	Correlation Coefficient	.012			.042	-.176
		Sig. (2-tailed)	.951			.820	.343
		N	31	0	0	31	31
	DXA g/cm2 trochanter	Correlation Coefficient	.137			.073	-.078
		Sig. (2-tailed)	.462			.697	.672
		N	31	0	0	31	31
	DXA T-score trochanter	Correlation Coefficient	.134			.072	-.079
		Sig. (2-tailed)	.473			.701	.675
		N	31	0	0	31	31
	DXA g/cm2 intertroch	Correlation Coefficient	.118			-.010	-.291
		Sig. (2-tailed)	.528			.958	.112
		N	31	0	0	31	31
	DXA T-score intertroch	Correlation Coefficient	.124			-.002	-.279
		Sig. (2-tailed)	.507			.991	.128
		N	31	0	0	31	31
	DXA result	Correlation Coefficient	.034			-.022	-.102
		Sig. (2-tailed)	.856			.905	.587
		N	31	0	0	31	31
	Z_score fingers	Correlation Coefficient	-.054			.007	-.078
		Sig. (2-tailed)	.756			.970	.656
		N	35	0	0	35	35
	Age (years)	Correlation Coefficient	-.161			-.067	-.068
		Sig. (2-tailed)	.080			.464	.530
		N	120	0	0	120	120
	Body Mass Index (BMI) kg/m2	Correlation Coefficient	-.134			-.182*	-.026
		Sig. (2-tailed)	.144			.047	.778
		N	120	0	0	120	120
	BMI category	Correlation Coefficient	-.114			-.140	-.024
		Sig. (2-tailed)	.215			.128	.794
		N	120	0	0	120	120
	Units sport 1 per week	Correlation Coefficient	-.167			.020	.159
		Sig. (2-tailed)	.068			.831	.084
		N	120	0	0	120	120
	Total units sport per week	Correlation Coefficient	-.208*			.009	.162
		Sig. (2-tailed)	.023			.918	.076
		N	120	0	0	120	120
	Total sports new	Correlation Coefficient	-.220*			.030	.145
		Sig. (2-tailed)	.016			.743	.114
		N	120	0	0	120	120
	IPAQ score	Correlation Coefficient	-.256**			.071	.099
		Sig. (2-tailed)	.005			.443	.283
		N	120	0	0	120	120
	Activity code	Correlation Coefficient	-.278**			.070	.138
		Sig. (2-tailed)	.002			.448	.131
		N	120	0	0	120	120
	No. of milk drinks per week	Correlation Coefficient	-.202*			-.016	-.044
		Sig. (2-tailed)	.028			.863	.635
		N	119	0	0	119	119
	No. of milk drinks per week (Banded)	Correlation Coefficient	-.169			.121	-.088
		Sig. (2-tailed)	.065			.187	.338
		N	120	0	0	120	120
	Daily calcium intake (mg)	Correlation Coefficient	-.058			.003	-.039
		Sig. (2-tailed)	.526			.975	.675
		N	120	0	0	120	120
	Calcium intake level	Correlation Coefficient	-.039			-.031	-.049
		Sig. (2-tailed)	.676			.734	.592
		N	120	0	0	120	120
	Rescaled calcium	Correlation Coefficient	-.058			.003	-.039
		Sig. (2-tailed)	.526			.975	.675
		N	120	0	0	120	120
	Ever smoked	Correlation Coefficient	.248**			-.004	.144
		Sig. (2-tailed)	.006			.961	.117
		N	120	0	0	120	120
	No. of years smoked	Correlation Coefficient	.253**			.011	.174
		Sig. (2-tailed)	.006			.906	.059
		N	118	0	0	118	118
	Number of cigarettes per day	Correlation Coefficient	.252*			-.015	.163
		Sig. (2-tailed)	.005			.871	.076
		N	120	0	0	120	120
	Total Cig	Correlation Coefficient	.266**			-.004	.165
		Sig. (2-tailed)	.004			.982	.074
		N	118	0	0	118	118
	Caffeine per week (mg)	Correlation Coefficient	.449**			-.015	.017
		Sig. (2-tailed)	.000			.869	.857
		N	120	0	0	120	120
	Caffeine per week (mg) (Banded)	Correlation Coefficient	.342**			-.024	.048
		Sig. (2-tailed)	.000			.797	.605
		N	120	0	0	120	120
	No. of carb. drinks per week	Correlation Coefficient	.915**			.040	.124
		Sig. (2-tailed)	.000			.667	.177
		N	120	0	0	120	120
	carbonated drinks	Correlation Coefficient	1.000			.048	.116
		Sig. (2-tailed)				.618	.205
		N	120	0	0	120	120
	Menarche age	Correlation Coefficient					
		Sig. (2-tailed)					
		N	0	0	0	0	0
	Menstrual regularity	Correlation Coefficient					
		Sig. (2-tailed)					
		N	0	0	0	0	0
	Sun exposure per day (mins)	Correlation Coefficient	.048			1.000	.065
		Sig. (2-tailed)	.618				.483
		N	120	0	0	120	120
	No. of broken bones	Correlation Coefficient	.116			.065	1.000
		Sig. (2-tailed)	.205			.483	
		N	120	0	0	120	120

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

a. Sex = Male

APPENDIX T – Correlations, Females

			QUS lowest heel	Right heel stiffness index	Right heel T-score	Left heel stiffness index	Left heel T score	DXA g/cm2 Total hip	DXA T-score Total hip	DXA g/cm2 neck	DXA T-score neck	DXA g/cm2 trochanter	DXA T-score trochanter	DXA g/cm2 intertroch
Spearman's rho	QUS lowest heel	Correlation Coefficient	1.000	.938**	.935**	.933**	.931**	.399**	.398**	.270	.283	.389**	.448**	.367**
		Sig. (2-tailed)	.	.000	.000	.000	.000	.013	.013	.101	.085	.023	.005	.023
		N	153	151	151	152	152	38	38	38	38	38	38	38
	Right heel stiffness index	Correlation Coefficient	.938**	1.000	.998**	.826**	.818**	.383*	.381*	.240	.251	.348*	.435**	.331*
		Sig. (2-tailed)	.000	.	.000	.000	.000	.018	.018	.147	.128	.032	.006	.042
		N	151	151	151	151	151	38	38	38	38	38	38	38
	Right heel T-score	Correlation Coefficient	.935**	.998**	1.000	.826**	.819**	.378*	.376*	.234	.246	.348*	.428**	.327*
		Sig. (2-tailed)	.000	.000	.	.000	.000	.019	.020	.157	.137	.033	.007	.045
		N	151	151	151	151	151	38	38	38	38	38	38	38
	Left heel stiffness index	Correlation Coefficient	.933**	.826**	.826**	1.000	.999**	.453**	.453**	.347*	.360*	.481**	.490**	.436**
		Sig. (2-tailed)	.000	.000	.000	.	.000	.004	.004	.033	.026	.013	.002	.006
		N	152	151	151	152	152	38	38	38	38	38	38	38
	Left heel T score	Correlation Coefficient	.931**	.819**	.819**	.999**	1.000	.461**	.460**	.364*	.381*	.432**	.519**	.462**
		Sig. (2-tailed)	.000	.000	.000	.000	.	.002	.002	.023	.018	.007	.001	.003
		N	152	151	151	152	152	38	38	38	38	38	38	38
	DXA g/cm2 Total hip	Correlation Coefficient	.399*	.383*	.378*	.453**	.461**	1.000	.999**	.862**	.858**	.931**	.962**	.972**
		Sig. (2-tailed)	.013	.018	.019	.004	.002	.	.000	.000	.000	.000	.000	.000
		N	38	38	38	38	38	38	38	38	38	38	38	38
	DXA T-score Total hip	Correlation Coefficient	.398*	.381*	.376*	.453**	.460**	.999**	1.000	.867**	.861**	.938**	.958**	.973**
		Sig. (2-tailed)	.013	.018	.020	.004	.002	.000	.	.000	.000	.000	.000	.000
		N	38	38	38	38	38	38	38	38	38	38	38	38
	DXA g/cm2 neck	Correlation Coefficient	.270	.240	.234	.347*	.364*	.862**	.867**	1.000	.998**	.769**	.788**	.804**
		Sig. (2-tailed)	.101	.147	.157	.033	.023	.000	.000	.	.000	.000	.000	.000
		N	38	38	38	38	38	38	38	38	38	38	38	38
	DXA T-score neck	Correlation Coefficient	.283	.251	.246	.360*	.381*	.858**	.861**	.998**	1.000	.759**	.785**	.797**
		Sig. (2-tailed)	.085	.128	.137	.026	.018	.000	.000	.000	.	.000	.000	.000
		N	38	38	38	38	38	38	38	38	38	38	38	38
	DXA g/cm2 trochanter	Correlation Coefficient	.389*	.348*	.348*	.481**	.432**	.931**	.938**	.769**	.759**	1.000	.946**	.880**
		Sig. (2-tailed)	.023	.032	.033	.013	.007	.000	.000	.000	.000	.	.000	.000
		N	38	38	38	38	38	38	38	38	38	38	38	38
	DXA T-score trochanter	Correlation Coefficient	.448**	.435**	.428**	.490**	.519**	.962**	.958**	.788**	.785**	.946**	1.000	.912**
		Sig. (2-tailed)	.005	.006	.007	.002	.001	.000	.000	.000	.000	.000	.	.000
		N	38	38	38	38	38	38	38	38	38	38	38	38
	DXA g/cm2 intertroch	Correlation Coefficient	.367*	.331*	.327*	.436**	.462**	.972**	.973**	.804**	.797**	.880**	.912**	1.000
		Sig. (2-tailed)	.023	.042	.045	.006	.003	.000	.000	.000	.000	.000	.000	.
		N	38	38	38	38	38	38	38	38	38	38	38	38
	DXA T-score intertroch	Correlation Coefficient	.366*	.334*	.329*	.434**	.462**	.975**	.975**	.807**	.800**	.884**	.916**	.999**
		Sig. (2-tailed)	.024	.041	.044	.006	.004	.000	.000	.000	.000	.000	.000	.000
		N	38	38	38	38	38	38	38	38	38	38	38	38
	DXA result	Correlation Coefficient	.342*	.282	.279	.409*	.424**	.865**	.866**	.812**	.811**	.636**	.823**	.827**
		Sig. (2-tailed)	.035	.087	.089	.011	.008	.000	.000	.000	.000	.000	.000	.000
		N	38	38	38	38	38	38	38	38	38	38	38	38
	Z_score fingers	Correlation Coefficient	-.121	-.028	-.021	-.172	-.168	-.008	-.013	.133	.142	-.053	-.061	-.023
		Sig. (2-tailed)	.402	.848	.884	.233	.273	.971	.955	.585	.540	.819	.792	.920
		N	50	50	50	50	50	21	21	21	21	21	21	21
	Age (years)	Correlation Coefficient	-.104	-.045	-.039	-.123	-.131	-.147	-.155	-.286	-.246	-.086	-.186	-.167
		Sig. (2-tailed)	.200	.586	.634	.131	.107	.378	.352	.106	.139	.566	.262	.315
		N	153	151	151	152	152	38	38	38	38	38	38	38
	Body Mass Index (BMI) kg/m2	Correlation Coefficient	.241**	.224**	.228**	.227**	.228**	.469**	.458**	.459**	.459**	.382**	.397**	.444**
		Sig. (2-tailed)	.003	.006	.005	.005	.005	.003	.004	.004	.004	.018	.014	.005
		N	153	151	151	152	152	38	38	38	38	38	38	38
	BMI category	Correlation Coefficient	.277**	.264**	.268**	.239**	.242**	.444**	.437**	.529**	.527**	.387**	.355**	.413**
		Sig. (2-tailed)	.001	.001	.001	.003	.003	.005	.006	.001	.001	.024	.029	.010
		N	153	151	151	152	152	38	38	38	38	38	38	38
	Units sport 1 per week	Correlation Coefficient	.148	.139	.138	.193*	.196*	.151	.150	.183	.180	.173	.214	.126
		Sig. (2-tailed)	.067	.090	.090	.017	.016	.364	.369	.273	.280	.300	.197	.452
		N	153	151	151	152	152	38	38	38	38	38	38	38
	Total units sport per week	Correlation Coefficient	.169*	.158	.158	.210**	.211**	.146	.143	.181	.178	.162	.203	.119
		Sig. (2-tailed)	.037	.053	.057	.010	.009	.386	.391	.278	.285	.331	.222	.476
		N	153	151	151	152	152	38	38	38	38	38	38	38
	Total sports new	Correlation Coefficient	.158*	.153	.151	.197*	.198*	.139	.137	.177	.174	.156	.198	.113
		Sig. (2-tailed)	.049	.060	.064	.015	.014	.404	.411	.289	.296	.343	.233	.501
		N	153	151	151	152	152	38	38	38	38	38	38	38
	IPAQ score	Correlation Coefficient	.024	.003	-.005	.084	.083	.308	.303	.289	.298	.292	.257	.301
		Sig. (2-tailed)	.771	.972	.955	.303	.313	.060	.065	.078	.069	.225	.119	.066
		N	152	150	150	151	151	38	38	38	38	38	38	38
	Activity code	Correlation Coefficient	.060	.042	.037	.117	.116	.343*	.336*	.317	.325*	.239	.310	.319
		Sig. (2-tailed)	.461	.611	.656	.153	.156	.035	.039	.052	.046	.149	.059	.051
		N	152	150	150	151	151	38	38	38	38	38	38	38
	No of milk drinks per week	Correlation Coefficient	.020	.051	.047	.020	.021	.408*	.410*	.417**	.433**	.443**	.373*	.413**
		Sig. (2-tailed)	.802	.533	.563	.803	.801	.011	.011	.009	.007	.005	.021	.010
		N	153	151	151	152	152	38	38	38	38	38	38	38
	No of milk drinks per week (Banded)	Correlation Coefficient	.065	.066	.064	.084	.092	.289	.294	.299	.317	.387*	.273	.294
		Sig. (2-tailed)	.425	.293	.307	.249	.260	.078	.074	.068	.052	.023	.097	.073
		N	153	151	151	152	152	38	38	38	38	38	38	38
	Daily calcium intake (mg)	Correlation Coefficient	-.098	-.126	-.125	-.080	-.092	.308	.309	.401*	.401*	.282	.320*	.296
		Sig. (2-tailed)	.229	.125	.128	.272	.261	.060	.059	.013	.013	.086	.044	.072
		N	152	150	150	151	151	38	38	38	38	38	38	38
	Calcium intake level	Correlation Coefficient	-.154	-.142	-.141	-.154	-.157	.287	.289	.326*	.333*	.264	.307	.266
		Sig. (2-tailed)	.058	.084	.086	.058	.063	.080	.079	.046	.041	.110	.061	.107
		N	152	150	150	151	151	38	38	38	38	38	38	38
	Rescaled calcium	Correlation Coefficient	-.098	-.126	-.125	-.080	-.092	.308	.309	.401*	.401*	.282	.320*	.296
		Sig. (2-tailed)	.229	.125	.128	.272	.261	.060	.059	.013	.013	.086	.044	.072
		N	152	150	150	151	151	38	38	38	38	38	38	38
	Ever smoked	Correlation Coefficient	.037	.041	.038	.032	.029							
		Sig. (2-tailed)	.649	.616	.632	.697	.727							
		N	153	151	151	152	152	38	38	38	38	38	38	38
	No of years smoked	Correlation Coefficient	.038	.041	.039	.033	.029							
		Sig. (2-tailed)	.646	.616	.632	.691	.721							
		N	153	151	151	152	152	38	38	38	38	38	38	38
	Number of cigarettes per day	Correlation Coefficient	.036	.040	.038	.032	.026							
		Sig. (2-tailed)	.655	.624	.640	.698	.728							
		N	153	151	151	152	152	38	38	38	38	38	38	38
	Total Cig	Correlation Coefficient	.037	.040	.038	.032	.029							
		Sig. (2-tailed)	.652	.622	.638	.696	.726							
		N	153	151	151	152	152	38	38	38	38	38	38	38
	Caffeine per week (mg)	Correlation Coefficient	.018	-.015	-.016	-.004	-.012	.028	.026	-.067	-.065	-.012	.068	.039
		Sig. (2-tailed)	.848	.854	.841	.960	.887	.864	.876	.690	.697	.944	.685	.816
		N	153	151	151	152	152	38	38	38	38	38	38	38
	Caffeine per week (mg) (Banded)	Correlation Coefficient	-.036	-.058	-.058	-.071	-.075	.087	.083	-.022	-.022	.031	.101	.085
		Sig. (2-tailed)	.659	.480	.482	.386	.358	.689	.708	.897	.897	.854	.545	.611
		N	153	151	151	152	152	38	38	38	38	38	38	38
	No of carb drinks per week	Correlation Coefficient	-.078	-.135	-.135	.006	.001	-.108	-.107	-.152	-.145	-.142	-.083	-.108
		Sig. (2-tailed)	.341	.099	.099	.944	.990	.518	.523	.361	.385	.394	.707	.519
		N	153	151	151	152	152	38	38	38	38	38	38	38
	carbonated drinks	Correlation Coefficient	-.125	-.165*	-.168*	-.051	-.056	-.083	-.086	-.095	-.088	-.086	-.051	-.068
		Sig. (2-tailed)	.124	.043	.039	.531	.501	.621	.607	.571	.611	.607	.763	.599
		N	153	151	151	152	152	38	38	38	38	38	38	38
	Menarche age	Correlation Coefficient	.017	-.031	-.032	.048	.042	.029	.027	-.075	-.083	.010	.064	.040
		Sig. (2-tailed)	.839	.702	.701	.560	.607	.865	.870	.655	.620	.954	.703	.810
		N	153	151	151	152	152	38	38	38	38	38	38	38
	Menstrual regularity	Correlation Coefficient	-.102	-.058	-.062	-.106	-.109	-.273	-.284	-.259	-.256	-.302	-.295	-.302
		Sig. (2-tailed)	.211	.492	.526	.193	.183	.097	.084	.116	.121	.066	.072	.066
		N	153	151	151	152	152	38	38	38	38	38	38	38
	Sun exposure per day (mins)	Correlation Coefficient	.148	.052	.050	.152	.142	.224	.229	.188	.212	.158	.203	.231
		Sig. (2-tailed)	.067	.528	.538	.062	.080	.176	.167	.232	.202	.340	.222	.162
		N	153	151	151	152	152	38	38	38	38	38	38	38
	No of broken bones	Correlation Coefficient	-.037	-.063	-.078	-.015	-.018	-.318	-.322*	-.230	-.225	-.332*	-.306	-.358*
		Sig. (2-tailed)	.652	.313	.342	.853	.828	.052	.049	.165	.174	.042	.062	.028
		N	153	151	151	152	152	38	38	38	38	38	38	38

			DXA T-score intertroch	DXA result	Z_score fingers	Age (years)	Body Mass Index (BMI) kg/m2	BMI category	Units sport 1 per week	Total units sport per week	Total sports new	IPAQ score	Activity code	No of milk drinks per week
Spearman rho	GUS lowest heel	Correlation Coefficient	.366**	.342**	-.121	-.164	.241**	.277**	.146	.169*	.159*	.024	.080	.020
		Sig. (2-tailed)	.024	.035	.402	.208	.003	.001	.067	.037	.049	.771	.461	.802
		N	38	38	50	153	153	153	153	153	153	152	152	153
	Right heel stiffness index	Correlation Coefficient	.334*	.282	-.028	.045	.224**	.264**	.139	.156	.153	.003	.042	.051
		Sig. (2-tailed)	.041	.087	.848	.586	.006	.001	.090	.053	.060	.972	.611	.533
		N	38	38	50	151	151	151	151	151	151	150	150	151
	Right heel T-score	Correlation Coefficient	.329*	.279	-.021	-.039	.226**	.268**	.138	.155	.151	-.005	.037	.047
		Sig. (2-tailed)	.044	.089	.884	.634	.005	.001	.095	.057	.064	.955	.656	.563
		N	38	38	50	151	151	151	151	151	151	150	150	151
	Left heel stiffness index	Correlation Coefficient	.434**	.408**	.172	-.123	.227**	.238**	.193*	.210**	.197*	.084	.117	.020
		Sig. (2-tailed)	.006	.011	.233	.131	.005	.003	.017	.010	.015	.303	.153	.803
		N	38	38	50	152	152	152	152	152	152	151	151	152
	Left heel T score	Correlation Coefficient	.442**	.424**	-.158	-.131	.229**	.242**	.198*	.211**	.199*	.083	.116	.021
		Sig. (2-tailed)	.004	.008	.273	.107	.005	.003	.016	.009	.014	.313	.158	.801
		N	38	38	50	152	152	152	152	152	152	151	151	152
	DXA g/cm2 Total hip	Correlation Coefficient	.975**	.865**	-.008	-.147	.469**	.444**	.151	.145	.139	.308**	.343**	.408**
		Sig. (2-tailed)	.000	.000	.971	.378	.003	.005	.364	.385	.404	.060	.035	.011
		N	38	38	21	38	38	38	38	38	38	38	38	38
	DXA T-score Total hip	Correlation Coefficient	.975**	.866**	-.013	-.155	.458**	.437**	.150	.143	.137	.303	.336*	.410**
		Sig. (2-tailed)	.000	.000	.955	.352	.004	.006	.369	.391	.411	.065	.039	.011
		N	38	38	21	38	38	38	38	38	38	38	38	38
	DXA g/cm2 neck	Correlation Coefficient	.807**	.812**	.133	-.208	.459**	.529**	.183	.181	.177	.286	.317	.417**
		Sig. (2-tailed)	.000	.000	.565	.106	.004	.001	.273	.278	.289	.078	.052	.009
		N	38	38	21	38	38	38	38	38	38	38	38	38
	DXA T-score neck	Correlation Coefficient	.800**	.811**	.142	-.245	.456**	.527**	.180	.178	.174	.298	.325*	.433**
		Sig. (2-tailed)	.000	.000	.540	.139	.004	.001	.280	.285	.298	.069	.046	.007
		N	38	38	21	38	38	38	38	38	38	38	38	38
	DXA g/cm2 trochanter	Correlation Coefficient	.884**	.838**	-.053	-.096	.382**	.367**	.173	.162	.158	.202	.239	.443**
		Sig. (2-tailed)	.000	.000	.819	.566	.018	.024	.300	.331	.343	.225	.149	.005
		N	38	38	21	38	38	38	38	38	38	38	38	38
	DXA T score trochanter	Correlation Coefficient	.916**	.823**	-.061	-.186	.397**	.355**	.214	.203	.198	.257	.310	.373**
		Sig. (2-tailed)	.000	.000	.792	.262	.014	.029	.197	.222	.233	.119	.059	.021
		N	38	38	21	38	38	38	38	38	38	38	38	38
	DXA g/cm2 intertroch	Correlation Coefficient	.999**	.837**	-.023	-.167	.444**	.413**	.126	.119	.113	.301	.318	.413**
		Sig. (2-tailed)	.000	.000	.920	.315	.005	.010	.452	.476	.501	.068	.051	.010
		N	38	38	21	38	38	38	38	38	38	38	38	38
	DXA T-score intertroch	Correlation Coefficient	1.000	.825**	-.020	-.160	.454**	.421**	.138	.132	.126	.313	.336*	.407**
		Sig. (2-tailed)		.000	.932	.338	.004	.008	.406	.428	.451	.056	.043	.011
		N	38	38	21	38	38	38	38	38	38	38	38	38
	DXA result	Correlation Coefficient	.825**	1.000	-.238	-.111	.457**	.422**	.105	.091	.085	.257	.250	.465**
		Sig. (2-tailed)	.000		.298	.509	.004	.008	.530	.587	.611	.119	.130	.003
		N	38	38	21	38	38	38	38	38	38	38	38	38
	Z_score fingers	Correlation Coefficient	-.020	-.238	1.000	-.183	-.363**	-.310*	.113	.113	.117	-.024	-.028	-.014
		Sig. (2-tailed)	.932	.298		.389	.002	.008	.347	.347	.331	.840	.871	.905
		N	21	21	72	72	72	72	71	71	71	71	71	72
	Age (years)	Correlation Coefficient	-.160	-.111	-.103	1.000	-.059	-.048	-.058	-.055	-.052	-.171*	-.194*	.024
		Sig. (2-tailed)	.338	.509	.389		.439	.545	.443	.469	.498	.024	.010	.756
		N	38	38	72	176	176	176	175	175	175	176	175	176
	Body Mass Index (BMI) kg/m2	Correlation Coefficient	.454**	.457**	-.363**	-.059	1.000	.917**	.070	.073	.084	.001	.037	.168*
		Sig. (2-tailed)	.004	.004	.002	.439		.000	.356	.338	.270	.989	.627	.026
		N	38	38	72	176	176	176	175	175	175	175	175	176
	BMI category	Correlation Coefficient	.421**	.422**	-.310**	-.048	.917**	1.000	.108	.116	.130	-.039	-.007	.119
		Sig. (2-tailed)	.008	.008	.008	.545	.000		.163	.125	.085	.609	.929	.116
		N	38	38	72	176	176	176	175	175	175	175	175	176
	Units sport 1 per week	Correlation Coefficient	.138	.105	.113	.058	.070	.108	1.000	.982**	.991**	.393**	.391**	.041
		Sig. (2-tailed)	.408	.530	.347	.443	.356	.163		.000	.000	.000	.000	.588
		N	38	38	71	175	175	175	175	175	175	174	174	175
	Total units sport per week	Correlation Coefficient	.132	.091	.113	-.055	.073	.116	.982**	1.000	.998**	.391**	.392**	.035
		Sig. (2-tailed)	.428	.587	.347	.469	.338	.125	.000		.000	.000	.000	.646
		N	38	38	71	175	175	175	175	175	175	174	174	175
	Total sports new	Correlation Coefficient	.126	.085	.117	-.052	.084	.130	.991**	.998**	1.000	.392**	.390**	.033
		Sig. (2-tailed)	.451	.611	.331	.498	.270	.085	.000	.000		.000	.000	.664
		N	38	38	71	175	175	175	175	175	175	174	174	175
	IPAQ score	Correlation Coefficient	.313	.257	-.024	-.171*	.001	-.039	.393**	.391**	.392**	1.000	.930**	.088
		Sig. (2-tailed)	.056	.119	.840	.024	.989	.609	.000	.000	.000		.000	.244
		N	38	38	71	175	175	175	174	174	174	175	175	175
	Activity code	Correlation Coefficient	.330*	.258	-.020	-.194*	.037	-.007	.391**	.392**	.390**	.930**	1.000	.095
		Sig. (2-tailed)	.043	.130	.871	.010	.627	.929	.000	.000	.000	.000		.208
		N	38	38	71	176	175	175	174	174	174	175	175	175
	No of milk drinks per week	Correlation Coefficient	.407**	.465**	-.014	-.024	.168*	.119	.041	.035	.033	.088	.095	1.000
		Sig. (2-tailed)	.011	.003	.905	.756	.026	.116	.588	.646	.664	.244	.208	
		N	38	38	72	176	176	176	175	175	175	175	175	176
	No of milk drinks per week (Banded)	Correlation Coefficient	.286	.337**	-.004	-.019	.156*	.094	.013	.012	.007	.088	.083	.840**
		Sig. (2-tailed)	.082	.038	.975	.798	.035	.214	.863	.871	.927	.248	.273	.000
		N	38	38	72	176	176	176	175	175	175	175	175	176
	Daily calcium intake (mg)	Correlation Coefficient	.280	.378**	.110	.012	-.089	-.036	.048	.045	.037	.090	.106	.416**
		Sig. (2-tailed)	.088	.019	.363	.874	.387	.634	.530	.558	.624	.235	.158	.000
		N	38	38	71	175	175	175	174	174	174	175	175	175
	Calcium intake level	Correlation Coefficient	.255	.378**	.119	.042	-.058	-.028	.008	-.004	-.007	.188	.108	.416**
		Sig. (2-tailed)	.122	.019	.323	.581	.512	.737	.920	.953	.926	.186	.151	.000
		N	38	38	71	175	175	175	174	174	174	175	175	175
	Rescaled calcium	Correlation Coefficient	.280	.378**	.110	.012	-.089	-.036	.048	.045	.037	.090	.106	.416**
		Sig. (2-tailed)	.088	.019	.363	.874	.387	.634	.530	.558	.624	.235	.158	.000
		N	38	38	71	175	175	175	174	174	174	175	175	175
	Ever smoked	Correlation Coefficient			-.224	.177*	.137	.113	.098	.108	.102	.034	.022	-.018
		Sig. (2-tailed)			.059	.019	.070	.136	.206	.159	.181	.659	.775	.810
		N	38	38	72	176	176	176	175	175	175	175	175	176
	No. of years smoked	Correlation Coefficient			-.224	.177*	.139	.115	.098	.102	.104	.036	.024	-.019
		Sig. (2-tailed)			.059	.018	.067	.130	.198	.181	.172	.638	.782	.804
		N	38	38	72	176	176	176	175	175	175	175	175	176
	Number of cigarettes per day	Correlation Coefficient			-.224	.177*	.137	.112	.095	.099	.101	.031	.021	-.018
		Sig. (2-tailed)			.059	.019	.071	.138	.210	.191	.183	.680	.784	.817
		N	38	38	72	176	176	176	175	175	175	175	175	176
	Total Cig	Correlation Coefficient			-.224	.177*	.138	.114	.097	.101	.103	.033	.023	-.018
		Sig. (2-tailed)			.059	.019	.068	.133	.203	.185	.176	.660	.765	.817
		N	38	38	72	176	176	176	175	175	175	175	175	176
	Caffeine per week (mg)	Correlation Coefficient	.028	.014	-.214	.037	.095	.053	.043	.058	.048	-.003	-.012	.087
		Sig. (2-tailed)	.869	.932	.071	.622	.210	.487	.576	.462	.525	.972	.870	.252
		N	38	38	72	176	176	176	175	175	175	175	175	176
	Caffeine per week (mg) (Banded)	Correlation Coefficient	.075	.036	-.178	.067	.080	.058	.038	.054	.047	.004	-.006	.087
		Sig. (2-tailed)	.654	.832	.135	.374	.295	.463	.604	.474	.537	.962	.905	.248
		N	38	38	72	176	176	176	175	175	175	175	175	176
	No. of carb. drinks per week	Correlation Coefficient	-.115	-.078	-.017	-.127	.024	-.064	.083	.064	.062	.054	.035	-.122
		Sig. (2-tailed)	.493	.644	.888	.093	.749	.396	.408	.397	.492	.479	.646	.108
		N	38	38	72	176	176	176	175	175	175	175	175	176
	carbonated drinks	Correlation Coefficient	.092	.016	-.046	-.058	-.115	-.140	-.025	-.020	-.026	.084	.074	-.094
		Sig. (2-tailed)	.584	.926	.738	.441	.130	.064	.738	.795	.736	.270	.329	.215
		N	38	38	72	176	176	176	175	175	175	175	175	176
	Menarche age	Correlation Coefficient	.033	.084	-.081	.104	-.229*	-.186*	-.025	-.018	-.027	.004	-.032	-.123
		Sig. (2-tailed)	.845	.617	.501	.168	.002	.014	.746	.813	.723	.963	.674	.104
		N	38	38	72	176	176	176	175	175	175	175	175	176
	[illegible]	Correlation Coefficient	-.309	-.213	.148	.033	-.040	-.064	-.082	-.072	-.086	-.119	-.133	-.139
		Sig. (2-tailed)	.059	.198	.220	.663	.597	.956	.418	.346	.304	.115	.079	.065
		N	38	38	72	176	176	176	175	175	175	175	175	176
	Sun exposure per day (mins)	Correlation Coefficient	.230	.288	-.116	.040	.006	-.033	.083	.093	.085	.285**	.291**	.093
		Sig. (2-tailed)	.165	.079	.331	.599	.936	.665	.274	.223	.262	.000	.000	.220
		N	38	38	72	176	176	176	175	175	175	175	175	176
	No. of broken bones	Correlation Coefficient	-.389*	-.234	.006	-.037	-.060	-.130	-.043	-.030	-.034	.052	.057	-.085
		Sig. (2-tailed)	.022	.158	.962	.623	.432	.085	.574	.695	.655	.497	.456	.392
		N	38	38	72	176	176	176	175	175	175	175	175	176

			No of milk drinks per week (numeric)	Daily calcium intake (mg)	Calcium intake level	Rescaled calcium	Ever smoked	No. of years smoked	Number of cigarettes per day	Total Cig	Caffeine per week (mg)	Caffeine per week (mg) (Banded)	No. of carb drinks per week
Spearman's rho	QUS lowest heel	Correlation Coefficient	.005	-.098	-.154	-.098	.037	.016	.036	.037	.016	-.036	-.078
		Sig. (2-tailed)	.425	.229	.058	.229	.649	.845	.655	.652	.848	.659	.341
		N	153	152	152	152	153	153	153	153	153	153	153
	Right heel stiffness index	Correlation Coefficient	.086	-.126	-.142	-.126	.041	.041	.040	.040	-.015	-.058	-.135
		Sig. (2-tailed)	.283	.125	.084	.125	.616	.616	.624	.622	.854	.480	.099
		N	151	150	150	150	151	151	151	151	151	151	151
	Right heel T-score	Correlation Coefficient	.084	-.126	-.141	-.125	.038	.039	.038	.039	-.016	-.060	-.135
		Sig. (2-tailed)	.307	.128	.086	.128	.632	.632	.640	.636	.841	.462	.099
		N	151	150	150	150	151	151	151	151	151	151	151
	Left heel stiffness index	Correlation Coefficient	.094	-.090	-.154	-.090	.032	.033	.032	.032	-.004	-.071	.006
		Sig. (2-tailed)	.249	.272	.058	.272	.697	.691	.699	.696	.960	.386	.944
		N	152	151	151	151	152	152	152	152	152	152	152
	Left heel T-score	Correlation Coefficient	.092	.092	-.157	-.092	.029	.029	.028	.029	-.012	-.075	.001
		Sig. (2-tailed)	.260	.261	.053	.261	.727	.721	.728	.726	.887	.358	.990
		N	152	151	151	151	152	152	152	152	152	152	152
	DXA gicm2 Total hip	Correlation Coefficient	.289	.308	.287	.308					.029	.087	-.108
		Sig. (2-tailed)	.078	.060	.080	.060					.864	.689	.518
		N	38	38	38	38	38	38	38	38	38	38	38
	DXA T-score Total hip	Correlation Coefficient	.294	.309	.289	.309					.026	.083	-.107
		Sig. (2-tailed)	.074	.059	.079	.059					.876	.708	.523
		N	38	38	38	38	38	38	38	38	38	38	38
	DXA gicm2 neck	Correlation Coefficient	.299	.401*	.326*	.401*					-.087	-.022	-.152
		Sig. (2-tailed)	.068	.013	.046	.013					.690	.897	.361
		N	38	38	38	38	38	38	38	38	38	38	38
	DXA T-score neck	Correlation Coefficient	.317	.401*	.333*	.401*					-.065	-.022	-.148
		Sig. (2-tailed)	.052	.013	.041	.013					.697	.897	.375
		N	38	38	38	38	38	38	38	38	38	38	38
	DXA gicm2 trochanter	Correlation Coefficient	.387*	.282	.264	.282					-.012	.031	-.142
		Sig. (2-tailed)	.023	.086	.110	.086					.944	.854	.394
		N	38	38	38	38	38	38	38	38	38	38	38
	DXA T-score trochanter	Correlation Coefficient	.273	.329*	.307	.329*					.068	.101	-.083
		Sig. (2-tailed)	.097	.044	.061	.044					.685	.545	.707
		N	38	38	38	38	38	38	38	38	38	38	38
	DXA gicm2 intertroch	Correlation Coefficient	.294	.296	.288	.296					.039	.085	-.108
		Sig. (2-tailed)	.073	.072	.107	.072					.816	.611	.519
		N	38	38	38	38	38	38	38	38	38	38	38
	DXA T-score intertroch	Correlation Coefficient	.268	.280	.255	.280					.026	.075	-.115
		Sig. (2-tailed)	.082	.088	.122	.088					.869	.654	.493
		N	38	38	38	38	38	38	38	38	38	38	38
	DXA result	Correlation Coefficient	.337*	.378*	.378*	.378*					.014	.036	-.078
		Sig. (2-tailed)	.038	.019	.019	.019					.932	.832	.644
		N	38	38	38	38	38	38	38	38	38	38	38
	Z_score fingers	Correlation Coefficient	-.084	.110	.119	.110	-.224	-.224	-.224	-.224	-.214	-.178	-.017
		Sig. (2-tailed)	.975	.383	.323	.383	.059	.059	.059	.059	.071	.135	.886
		N	72	71	71	71	72	72	72	72	72	72	72
	Age (years)	Correlation Coefficient	-.019	.012	.042	.012	.177*	.177*	.177*	.177*	.037	.067	-.127
		Sig. (2-tailed)	.798	.874	.581	.874	.019	.018	.019	.019	.622	.374	.093
		N	176	175	175	175	176	176	176	176	176	176	176
	Body Mass Index (BMI) kg/m2	Correlation Coefficient	.159*	-.088	-.050	-.089	.137	.139	.137	.138	.095	.080	-.024
		Sig. (2-tailed)	.035	.367	.512	.367	.070	.067	.071	.068	.210	.235	.749
		N	176	175	175	175	176	176	176	176	176	176	176
	BMI category	Correlation Coefficient	.094	-.038	-.028	-.038	.113	.115	.112	.114	.053	.056	-.054
		Sig. (2-tailed)	.214	.634	.737	.634	.136	.130	.138	.133	.487	.463	.398
		N	176	175	175	175	176	176	176	176	176	176	176
	Units sport 1 per week	Correlation Coefficient	.013	.048	.008	.048	.096	.098	.095	.097	.043	.039	.083
		Sig. (2-tailed)	.863	.530	.920	.530	.206	.194	.210	.203	.576	.604	.499
		N	175	174	174	174	175	175	175	175	176	175	175
	Total units sport per week	Correlation Coefficient	.012	.045	-.004	.045	.100	.102	.099	.101	.058	.054	.084
		Sig. (2-tailed)	.871	.556	.953	.556	.189	.181	.191	.185	.462	.474	.397
		N	175	174	174	174	175	175	176	175	175	175	175
	Total sports now	Correlation Coefficient	.007	.037	-.007	.037	.102	.104	.101	.103	.048	.047	.052
		Sig. (2-tailed)	.927	.624	.926	.624	.181	.172	.183	.176	.525	.537	.492
		N	175	174	174	174	175	175	175	175	175	175	175
	IPAQ score	Correlation Coefficient	.089	.090	.100	.090	.034	.036	.031	.033	-.003	.004	.054
		Sig. (2-tailed)	.248	.235	.186	.235	.659	.638	.680	.660	.972	.962	.479
		N	175	175	175	175	175	175	175	175	175	175	175
	Activity code	Correlation Coefficient	.083	.109	.108	.109	.022	.024	.021	.023	-.012	-.009	.035
		Sig. (2-tailed)	.273	.150	.151	.150	.775	.752	.784	.765	.870	.905	.648
		N	175	175	174	175	175	175	175	175	175	175	175
	No of milk drinks per week	Correlation Coefficient	.840**	.416**	.416**	.416**	-.018	-.018	-.018	-.016	-.087	-.087	-.122
		Sig. (2-tailed)	.000	.000	.000	.000	.810	.804	.817	.817	.252	.248	.106
		N	176	175	175	175	176	176	176	176	176	176	176
	No of milk drinks per week (Banded)	Correlation Coefficient	1.000	.360**	.371**	.360**	.007	.006	.007	.007	-.025	-.029	-.038
		Sig. (2-tailed)	.	.000	.000	.000	.927	.934	.927	.927	.738	.704	.610
		N	176	175	175	175	176	176	176	176	176	176	176
	Daily calcium intake (mg)	Correlation Coefficient	.360**	1.000	.890**	1.000**	.108	.109	.108	.110	.088	.081	.025
		Sig. (2-tailed)	.000	.	.000	.	.155	.150	.151	.147	.241	.421	.741
		N	175	175	175	175	175	175	175	175	175	175	175
	Calcium intake level	Correlation Coefficient	.371**	.890**	1.000	.890**	.113	.114	.113	.115	.081	.065	.005
		Sig. (2-tailed)	.000	.000	.	.000	.137	.133	.138	.131	.288	.395	.944
		N	175	175	175	175	175	175	175	175	175	175	175
	Rescaled calcium	Correlation Coefficient	.360**	1.000**	.890**	1.000	.108	.109	.108	.110	.088	.081	.025
		Sig. (2-tailed)	.000	.	.000	.	.155	.150	.151	.147	.241	.421	.741
		N	175	175	175	175	175	175	175	175	175	175	175
	Ever smoked	Correlation Coefficient	.007	.108	.113	.108	1.000	1.000**	1.000**	1.000**	.080	.080	.028
		Sig. (2-tailed)	.927	.155	.137	.155	.	.000	.000	.000	.288	.291	.708
		N	176	175	175	175	176	176	176	176	176	176	176
	No of years smoked	Correlation Coefficient	.006	.109	.114	.109	1.000**	1.000	1.000**	1.000**	.081	.080	.022
		Sig. (2-tailed)	.934	.150	.133	.150	.000	.	.000	.000	.288	.294	.770
		N	176	175	175	175	176	176	176	176	176	176	176
	Number of cigarettes per day	Correlation Coefficient	.007	.108	.113	.108	1.000**	1.000**	1.000	1.000**	.080	.080	.020
		Sig. (2-tailed)	.927	.151	.136	.151	.000	.000	.	.000	.291	.291	.795
		N	176	175	175	175	176	176	176	176	176	176	176
	Total Cig	Correlation Coefficient	.007	.110	.115	.110	1.000**	1.000**	1.000**	1.000	.081	.080	.021
		Sig. (2-tailed)	.927	.147	.131	.147	.000	.000	.000	.	.287	.291	.777
		N	176	175	175	175	176	176	176	176	176	176	176
	Caffeine per week (mg)	Correlation Coefficient	-.025	.088	.081	.088	.080	.081	.080	.081	1.000	.942**	.471**
		Sig. (2-tailed)	.738	.241	.288	.241	.288	.288	.291	.287	.	.000	.000
		N	176	175	175	175	176	176	176	176	176	176	176
	Caffeine per week (mg) (Banded)	Correlation Coefficient	-.029	.081	.065	.081	.080	.080	.080	.080	.942**	1.000	.405**
		Sig. (2-tailed)	.704	.421	.395	.421	.291	.294	.291	.291	.000	.	.000
		N	176	175	175	175	176	176	176	176	176	176	176
	No. of carb. drinks per week	Correlation Coefficient	.038	.025	.005	.025	.020	.022	.020	.021	.471**	.405**	1.000
		Sig. (2-tailed)	.610	.741	.944	.741	.788	.778	.795	.777	.000	.000	.
		N	176	175	175	175	176	176	176	176	176	176	176
	carbonated drinks	Correlation Coefficient	.081	-.080	.087	-.080	-.020	-.019	-.022	-.020	.376**	.350**	.757**
		Sig. (2-tailed)	.985	.237	.202	.237	.790	.807	.772	.790	.000	.000	.000
		N	176	175	175	175	176	176	176	176	176	176	176
	Menarche age	Correlation Coefficient	-.087	.003	-.001	.003	.088	.088	.085	.088	.083	.074	.070
		Sig. (2-tailed)	.374	.969	.984	.969	.382	.382	.389	.386	.221	.327	.353
		N	176	175	175	175	176	176	176	176	176	176	176
	Menstrual regularity	Correlation Coefficient	-.074	.009	.037	.009	.031	.029	.031	.029	.127	.138	.089
		Sig. (2-tailed)	.327	.907	.630	.907	.682	.704	.682	.704	.093	.067	.151
		N	176	175	175	175	176	176	176	176	176	176	176
	Sun exposure per day (mins)	Correlation Coefficient	.115	.275**	.187*	.275**	.151*	.151*	.151*	.151*	.136	.128	.051
		Sig. (2-tailed)	.129	.000	.013	.000	.045	.045	.046	.045	.072	.091	.501
		N	176	175	175	175	176	176	176	176	176	176	176
	No. of broken bones	Correlation Coefficient	-.052	.021	.015	.021	-.082	-.082	-.082	-.082	.160*	.174*	.070
		Sig. (2-tailed)	.490	.783	.841	.783	.280	.280	.280	.280	.034	.021	.356
		N	176	175	175	175	176	176	176	176	176	176	176

End Matters

			carbonated drinks	Menarche age	Menstrual regularity	Sun exposure per day (mins)	No. of broken bones
Spearman's rho	QUS lowest heel	Correlation Coefficient	-.125	.017	-.102	.149	-.037
		Sig. (2-tailed)	.124	.839	.211	.067	.652
		N	153	153	153	153	153
	Right heel stiffness index	Correlation Coefficient	-.165*	-.031	-.066	.052	-.083
		Sig. (2-tailed)	.043	.702	.492	.526	.313
		N	151	151	151	151	151
	Right heel T score	Correlation Coefficient	-.168*	-.032	-.052	.050	-.078
		Sig. (2-tailed)	.039	.701	.526	.538	.342
		N	151	151	151	151	151
	Left heel stiffness index	Correlation Coefficient	-.051	.048	-.108	.152	-.015
		Sig. (2-tailed)	.531	.560	.193	.062	.853
		N	152	152	152	152	152
	Left heel T score	Correlation Coefficient	-.055	.042	-.108	.142	-.018
		Sig. (2-tailed)	.501	.607	.183	.080	.828
		N	152	152	152	152	152
	DXA gicm2 Total hip	Correlation Coefficient	-.083	.029	-.273	.224	-.318
		Sig. (2-tailed)	.621	.865	.097	.178	.052
		N	38	38	38	38	38
	DXA T-score Total hip	Correlation Coefficient	-.086	.027	-.284	.229	-.322*
		Sig. (2-tailed)	.607	.870	.084	.167	.049
		N	38	38	38	38	38
	DXA gicm2 neck	Correlation Coefficient	-.095	-.075	-.258	.198	-.230
		Sig. (2-tailed)	.571	.655	.116	.232	.165
		N	38	38	38	38	38
	DXA T score neck	Correlation Coefficient	-.085	-.083	-.256	.212	-.225
		Sig. (2-tailed)	.611	.620	.121	.202	.174
		N	38	38	38	38	38
	DXA gicm2 trochanter	Correlation Coefficient	-.086	.010	-.302	.158	-.332*
		Sig. (2-tailed)	.607	.954	.066	.340	.042
		N	38	38	38	38	38
	DXA T-score trochanter	Correlation Coefficient	-.051	.064	-.295	.203	-.306
		Sig. (2-tailed)	.763	.703	.072	.222	.062
		N	38	38	38	38	38
	DXA gicm2 inteltroch	Correlation Coefficient	-.088	.040	-.302	.231	-.358*
		Sig. (2-tailed)	.599	.810	.066	.162	.026
		N	38	38	38	38	38
	DXA T-score intertroch	Correlation Coefficient	-.092	.033	-.308	.230	-.369*
		Sig. (2-tailed)	.584	.845	.059	.165	.022
		N	38	38	38	38	38
	DXA result	Correlation Coefficient	.016	.084	-.213	.288	-.234
		Sig. (2-tailed)	.926	.617	.198	.079	.158
		N	38	38	38	38	38
	Z_score fingers	Correlation Coefficient	-.040	-.081	.146	-.116	.008
		Sig. (2-tailed)	.738	.501	.220	.331	.942
		N	72	72	72	72	72
	Age (years)	Correlation Coefficient	-.058	.104	.033	.040	-.037
		Sig. (2-tailed)	.441	.168	.661	.599	.623
		N	176	176	176	176	176
	Body Mass Index (BMI) kg/m2	Correlation Coefficient	-.116	-.228**	-.040	.006	-.060
		Sig. (2-tailed)	.130	.002	.597	.936	.432
		N	176	176	176	176	176
	BMI category	Correlation Coefficient	-.140	-.186*	-.004	-.033	-.130
		Sig. (2-tailed)	.064	.014	.956	.665	.085
		N	176	176	176	176	176
	Units sport 1 per week	Correlation Coefficient	-.025	-.025	.082	.083	-.043
		Sig. (2-tailed)	.738	.746	.418	.274	.574
		N	175	175	175	175	175
	Total units sport per week	Correlation Coefficient	-.020	-.018	-.072	.093	-.030
		Sig. (2-tailed)	.798	.813	.346	.223	.695
		N	175	175	175	175	175
	Total sports new	Correlation Coefficient	-.028	-.027	-.066	.085	-.034
		Sig. (2-tailed)	.738	.723	.384	.262	.655
		N	175	175	175	175	175
	IPAQ score	Correlation Coefficient	.084	.004	-.119	.285*	.052
		Sig. (2-tailed)	.270	.963	.115	.000	.497
		N	175	175	175	175	175
	Activity code	Correlation Coefficient	.074	-.032	-.133	.291*	.057
		Sig. (2-tailed)	.329	.674	.079	.000	.456
		N	175	175	175	175	175
	No of soft drinks per week	Correlation Coefficient	-.084	-.123	-.130	.093	-.085
		Sig. (2-tailed)	.215	.104	.085	.220	.262
		N	176	176	176	176	176
	No of soft drinks per week (Banded)	Correlation Coefficient	.001	-.067	-.074	.115	-.052
		Sig. (2-tailed)	.985	.374	.327	.129	.498
		N	176	176	176	176	176
	Daily calcium intake (mg)	Correlation Coefficient	.090	.003	.008	.275**	.021
		Sig. (2-tailed)	.237	.969	.907	.000	.783
		N	175	175	175	175	175
	Calcium intake level	Correlation Coefficient	-.067	-.001	.037	.187*	.015
		Sig. (2-tailed)	.202	.984	.630	.013	.841
		N	175	175	175	175	175
	Rescaled calcium	Correlation Coefficient	.090	.003	.009	.275**	.021
		Sig. (2-tailed)	.237	.969	.907	.000	.783
		N	175	175	175	175	175
	Ever smoked	Correlation Coefficient	-.020	.068	.031	.151*	-.082
		Sig. (2-tailed)	.790	.382	.682	.045	.280
		N	176	176	176	176	176
	No. of years smoked	Correlation Coefficient	-.019	.068	.029	.151*	-.082
		Sig. (2-tailed)	.807	.382	.704	.045	.280
		N	176	176	176	176	176
	Number of cigarettes per day	Correlation Coefficient	-.022	.065	.031	.151*	-.082
		Sig. (2-tailed)	.772	.389	.682	.046	.280
		N	176	176	176	176	176
	Total Cig	Correlation Coefficient	-.020	.068	.029	.151*	-.082
		Sig. (2-tailed)	.790	.386	.704	.045	.280
		N	176	176	176	176	176
	Caffeine per week (mg)	Correlation Coefficient	.370*	.083	.127	.138	.160*
		Sig. (2-tailed)	.000	.221	.093	.072	.034
		N	176	176	176	176	176
	Caffeine per week (mg) (Banded)	Correlation Coefficient	.358**	.074	.138	.128	.174*
		Sig. (2-tailed)	.000	.327	.067	.091	.021
		N	176	176	176	176	176
	No. of carb drinks per week	Correlation Coefficient	.757**	.070	.109	.081	.070
		Sig. (2-tailed)	.000	.353	.151	.501	.356
		N	176	176	176	176	176
	carbonated drinks	Correlation Coefficient	1.000	.031	.153*	.019	.061
		Sig. (2-tailed)	.	.682	.043	.801	.418
		N	176	176	176	176	176
	Menarche age	Correlation Coefficient	.031	1.000	.186*	.127	-.054
		Sig. (2-tailed)	.682	.	.012	.093	.473
		N	176	176	176	176	176
	Menstrual regularity	Correlation Coefficient	.153*	.186*	1.000	-.100	.125
		Sig. (2-tailed)	.043	.012	.	.188	.098
		N	176	176	176	176	176
	Sun exposure per day (mins)	Correlation Coefficient	.019	.127	-.100	1.000	.092
		Sig. (2-tailed)	.801	.093	.188	.	.225
		N	176	176	176	176	176
	No. of broken bones	Correlation Coefficient	.061	-.054	.125	.092	1.000
		Sig. (2-tailed)	.418	.473	.098	.225	.
		N	176	176	176	176	176

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

a. Sex = Female