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The effect of long term training on the bone mineral density and muscle strength of perimenopausal athletes

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The Effect of Long Term Training on the Bone Mineral Density and Muscle Strength of Perimenopausal Athletes

by

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USE OF THESIS

The Use of Thesis statement is not included in this version of the thesis.

Abstract.

The aim of this research was to determine if long term training (20 years+) in a high impact weight bearing sport (netball/basketball: NB/BB), a low impact weight-bearing sport (running/field hockey: GEN) and a non weight-bearing sport, swimming (SWI) produced a positive relationship with regional bone mineral density (BMD) and muscle strength.

Method.

Three groups of perimenopausal athletes (n=20) plus a control group (CON) (n=20) had Total Body BMD and body composition measured by DEXA (Hologic QDR 2000) and isometric strength of dominant arm flexors and leg extensors by a strain tensiometer connected to a strength chair. Differences between groups were determined by ANOVA followed by Scheffe Test and correlations by Pearson r. General characteristics, including age , height, weight and calcium intake showed no statistical differences.

Results.

The BB/NB group (1.150 g/cm^2) showed significantly higher Total Body BMD than the SWI (1.061 g/cm^2) and CON (1.024 g/cm^2) groups. The GEN group (1.118 g.cm^2) registered a significant difference between the CON group. BB/NB group (1.203 g/cm^2) had significantly higher regional leg BMD than the SWI (1.107 g/cm^2) and the CON (1.046 g/cm^2). The GEN group (1.179 g/cm^2) had significantly higher leg BMD than the CON group. Quadriceps strength was significantly correlated with leg BMD in the BB/NB (r=.57), SWI (r=.67) and GEN (r=.50). Regional arm BMD had a significant difference between BB/NB (0.733 g/cm^2) and CON (0.666 g/cm^2). No significant differences were found in arm strength between groups although BB/NB (F=4.2) were significantly stronger in the quadriceps than the CON. The athletic groups all registered significantly lower % Fat (BB/NB 30.9%, SWI 29.0%, GEN 31.1%) than the CON (39.6%). There was no significant relationship with BMD and calcium intake.

Conclusions.

Results indicate intensity of exercise, mediated through high impact activity, may be more important than body size in the determination of BMD. The style of activity may be important in developing regional BMD. Athletic groups showed significant relationships of leg strength to leg BMD but only the swimming group, which is an arm orientated activity, had a significant relationship between arm strength and arm BMD.

Declaration.

"I certify that this thesis does not incorporate, without acknowledgement, any material previously submitted for a degree or diploma in any institution of higher education and that, to the best of my knowledge and belief, it does not contain any material previously published or written by another person except where due reference is made in the text".

Signature: _____

Date: 5-9-94.

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Chapter One

Introduction.

1.1 Background to the Study.

With age there is a loss of bone mineral density and muscle strength that is virtually inevitable (Oyster, Morton & Linnell, 1984). Independent living and general quality of life can be affected if skeletal and muscle health are poor (Shangold, 1990). Post-menopausal females in particular are at risk of developing low bone mineral density due to estrogen deficiencies which can lead to high rates of bone loss in the first five to ten years after menopause (Eisman, 1991).

Age-related bone loss, a condition known as osteoporosis is concomitant with a greater risk of fracture (Drinkwater, 1993). Once osteoporosis is established the debilitating effects are very difficult to reverse (Eisman, 1991). Consequently prevention of osteoporosis is an important management strategy (Eisman, Kelly, Morrison, Pocock, Yeoman, Birmingham & Sambrook, 1993).

The bone density that is attained by middle age is dependent on bone mass accrued as well as the rate of loss of bone tissue (Ott, 1990). There are several factors which have been found to impact on the accumulation of bone tissue

such as heredity (Krall & Dawson-Hughes, 1993), smoking (Pocock, Eisman, Kelly, Sambrook & Yeates, 1989; Slemenda, Hui, Longcope & Johnston, 1989; Mellstrom, Rundgren, Jagenburg, Steen & Svanborg, 1982), alcohol (Johnell, Nilsson & Wiklund, 1982), race (Nelson, Kleerekoper, Peterson & Parfitt, 1993; Liel, Edwards, Shary, Spicer, Gordon & Bell, 1988), gender (Matkovic, Ilich & Hsieh, 1993), body size (Dawson-Hughes, Krall & Harris, 1993), diet (Kelly, Eisman & Sambrook, 1990; Dawson-Hughes *et al.*, 1993), endocrine status (Matkovich *et al.*, 1993; Arnaud, 1993; Buchanan, Myers, Lloyd, Leuenberger & Demiers, 1988) and exercise (Drinkwater, 1993, Leichter, Simkin, Margulies, Bivas, Steinberg, Giladi & Milgrom, 1989; Block, Friedlander, Brooks, Steiger, Stubbs & Genant, 1989).

The ability to produce muscular force decreases with age due to loss of motor units, decreased metabolism and atrophy of muscle tissue (Hopp, 1993). Lack of muscle strength can be extremely disabling. Rising out of a chair or visiting the toilet can become major tasks which may not be able to be performed unaided (Jones & Round, 1990).

The association between muscle strength and bone mineral density is not clear but there is some evidence of a positive relationship (Snow-Harter, Bouxsein, Lewis, Charette, Weinstein & Marcus, 1990; Kyllonen, Vaananen, Heikkinen, Kurttila-Matero, Martikkala & Vanharanta, 1991). Osteoporotic women have also been found to have lower back (extensors) strength values

than normal age-matched women (Sinaki, Khosla, Limburg, Rogers & Murtaugh, 1993). Muscular strength can certainly be implicated however as a factor in the incidence of falls leading to bone fracture (Jonsson, Ringsberg, Josefsson, Johnell & Birch-Jensen, 1992; Drinkwater, 1993).

1.2 Significance of the Study.

Developing and maintaining bone mass is a major strategy in coping with age-related bone deterioration. There are increasing indications that exercise can have a significant impact on bone tissue (McCulloch, Bailey, Whalen, Houston, Faulkner & Craven, 1992; Eisman *et al.*, 1993). Furthermore, the age when the exercise occurs also appears to be of increasing importance. The period when bone mass is maximized is uncertain (Ott, 1990), however evidence is accumulating that peak bone mineral density may occur during adolescence (Snow-Harter & Marus, 1991; Gilsanz, Gibbens, Carlson, Boechat, Cann & Schulz, 1988; Matkovic, Fontana, Tominac, Goel & Chestnut, 1990). Exercise has also been linked with maintenance of bone density (Dalsky, Stocke & Ehsani, 1988; Grove & Londeree, 1992), although this has not been firmly established (Snow-Harter & Marcus, 1991). To prevent osteoporosis it is essential to develop and maintain maximal bone mineral density. The establishment of appropriate exercise protocols along with suitable lifestyle practices, such as adequate nutrition would be of benefit to all females in the optimisation of skeletal health.

1.3 Purpose of the Study.

This study aims to determine if twenty years or more of athletic training and competition in women involved in weight-bearing or non-weight-bearing disciplines has a positive effect on bone mineral density and muscle strength. It further aims to differentiate between weight-bearing and non-weight- bearing exercise and the resultant effect on muscle strength and bone mineral density.

Weight-bearing athletes experience a different intensity of training. Netball is a game played on hard surfaces, involving rapid acceleration and deceleration which can generate forces up to 4.6 times body weight (Steele & Milburn, 1987). Hockey is a game often played on grass where running is a more common characteristic. To my knowledge, there has been no research conducted into the impact forces generated by playing hockey, although running has been found to generate ground reaction forces of 2.5 - 3.0 times body weight (Cavanagh & Lafortune, 1980). Higher intensities of loading produce a greater "osteogenic response" (Lanyon, 1992) which may be reflected in the bone mineral density of weight bearing athletes. Swimming by contrast is a non-weight-bearing activity which is associated with improved cardio-vascular function and muscle strength (Orwoll, Ferar, Oviatt, McClung & Huntington, 1989). The effects of gravity however are negated and less resistance is encountered than in weight-bearing activities.

1.4 Hypotheses.

1. There will be a significant difference in bone mineral density and muscle strength between the control and experimental groups.

2. There will be a significant difference in bone mineral density between experimental subjects who are involved in weight-bearing activities and experimental subjects involved in non-weight-bearing activities.

3. The bone mineral density of experimental and control subjects will be positively correlated to high calcium intake and body composition.

1.5 Definition of Terms.

1. Bone mineral content : is the mineral content in grams (LeBlanc, Schneider, Engelbretson & Evans, 1990).

2. Bone mineral density: refers to mass per unit area of bone tissue and is expressed in g/cm^2 (Mazess, Barden, Bisek & Hanson, 1990)

3. Body composition: body is divided into 2 sections; adipose tissue and lean mass (Johansson, Forslund, Sjodin, Mallmin, Hambraeus & Ljunghall, 1993) which as measured by DEXA is soft tissue.

4. High calcium intake: The recommended daily allowance is 800 mg/ day (Angus, Sambrook, Pocock & Eisman, 1988)

5. Long term training: defined as continuous involvement in the activity, once or twice a week for a minimum of 20 years.

6. Weight-bearing activities: considered to be activities which provide mechanical loading through muscular contractions and the force of gravity (McCulloch *et al.*, 1992).

7. Non-weight- bearing: considered to be activities in which the body was active, but supported.

8. Osteoporosis: a reduction in bone mass per unit volume to a level that may lead to fracture (Halle, Smidt, O'Dwyer & Lin, 1990)

9. Strain: a deformation or change in shape caused by a load of some kind (Frost, 1988).

10. Remodelling: turning over or replacing bone tissue (Frost, 1988).

1.6 Organization of the Thesis.

Chapter One provides a discussion of the background, significance and purpose of the study. Hypotheses and definitions of major terms are presented. Chapter Two reviews the literature, discussing musculoskeletal development in conjunction with related literature on calcium, exercise, body composition and densitometry.

Chapter Three describes the theoretical framework and study design. Methodology including subject selection, instruments of measurement, equipment and data collection procedures are contained in Chapter Four.

Results and analysis of data are presented in Chapter Five. The thesis concludes with a discussion of the findings and their implications in Chapter Six. Limitations of the study are also identified. Conclusions are related to the literature and recommendations for future research are noted.

Chapter Two

Literature Review.

2.1 Introduction.

Shepherd (1987) describes aging as

"a diminished capacity to regulate the internal environment (impaired homeostasis) and a reduced probability of survival".

With age there is a general decline in the physical capacities, but this may reflect a less active lifestyle rather than an overall functional decrease (Pollock, Lowenthal, Graves & Carroll, 1992). Maintaining an active lifestyle may lessen the effects of the aging process and produce a more positive and satisfying lifestyle (Berger, 1989). In the musculoskeletal system there are age related losses of both muscle and bone tissue (Pollock *et al.*, 1992). At the cellular level, enzyme activity decreases, protein synthesis is slower, cellular repair mechanisms deteriorate along with an accompanying decline in overall metabolic activity (Shepherd, 1987). This review focuses on the effects of aging and exercise on the musculoskeletal system.

2.2 The Skeletal System.

2.2.1 Introduction.

The skeletal system is composed of dynamic tissue which is able to adapt and change in response to its environmental conditions. Main influences on bone mineral density are hormonal and nutritional status (Dalsky, 1990), genetic inheritance (Lanyon, 1992; Kelly *et al* ., 1990; Krall & Dawson-Hughes, 1993) and amount of physical activity or mechanical usage (Frost, 1988). Bone has a number of functions including mechanical support, immunology (lymphocytes), protection of soft tissue, haemopoiesis and is a storehouse of minerals (Parfitt, 1990). Under endocrine control, bone is able to mobilize and release certain minerals, notably the calcium and phosphate ions, into the blood stream and absorb and incorporate mineral into bone tissue as required by the body (Mariëb, 1989).

The skeleton is composed of two main types of calcified tissue, cortical and trabecular bone. The skeleton has 80% cortical bone , which is dense, smooth bone consisting of haversian systems: concentric rings of hard bone matrix around a central canal. Trabecular bone, by contrast consists of horizontal and vertical lattice-like structures called trabeculae which are enclosed in a sheath of cortical bone (Snow-Harter & Marcus, 1991). The arrangement of trabeculae is designed for maximum strength with the available material

(Aisenbrey & DePaepe, 1992). Young bone will display thick vertical trabeculae connected by horizontal trabeculae but with age the lattice may become disconnected (Snow-Harter & Marcus, 1991) as the horizontal trabeculae, which act as "cross-braces" disappear (Aisenbrey & DePaepe, 1992).

The general orientation of the trabeculae is similar in most individuals but specific variations are determined by the loading history experienced by the particular bone (Carter, Fyhrie & Whalen, 1987). Cortical, or compact bone is found mainly in the appendicular skeleton whereas trabecular or cancellous bone is predominantly to be found in the vertebrae, or axial skeleton. There is also substantial trabecular bone found in the proximal end of the femur . The vertebrae and femur are two established fracture sites (Snow-Harter & Marcus, 1991).

2.2.2 Remodelling

Bone cells only constitute a very small fraction of bone by weight but are very important in maintaining the structural integrity of the tissue (Martin, 1985). There are three main types of bone cell. Osteoblasts, which are derived from the stromal stem cells of bone marrow, are able to secrete collagen which forms the matrix for salt deposition and are the bone forming cells (Parfitt, 1990). Osteocytes, which are mature osteoblasts and are no longer able to form matrix, and osteoclasts which are the largest but least

numerous cell, which resorb the minerals from bone back into solution in the blood (Marieb, 1989).

Bone growth has been found to be regulated by a system of remodelling (Martin & Burr, 1989). Remodelling has a fourfold purpose. It prevents the accumulation of old tissue, which is more susceptible to fatigue, and replaces biomechanically unsound bone (Dalsky, 1990). Secondly, it maintains mineral homeostasis (Dalsky, 1990; Parfitt , 1990) and thirdly it ensures there is sufficient bone tissue strategically placed to withstand the load bearing or mechanical usage that occurs at that site (Lanyon, 1992). It also allows for growth. The rates of remodelling vary considerably in different stages of life. In adolescence, remodelling would be likely to cause a net gain in bone tissue, whilst in old age the likely outcome would be a net loss (Marieb, 1989). The summation of all remodelling activity and frequency will determine the overall state of the skeleton (Parfitt, 1990; Lanyon, 1992).

The bone remodelling cycle has four distinct stages. Activation involves preparation of the site to be remodelled, recruitment of osteoclasts and the initiation of resorption (Martin, 1985; Parfitt, 1990). Osteoclasts are then able to begin resorption by enzymatic activity. Collagen is broken down and minerals, notably calcium, enter the extracellular fluid (Parfitt, 1990). The third stage is reversal where osteoclast action declines and osteoblastic activity promotes collagen formation, followed by mineralisation of the new

matrix. Bone formation involves two main processes: synthesis of the collagenous matrix, which determines the volume of bone and mineralisation of the newly formed matrix which determines the density of bone (Parfitt, 1990). Mineralisation is a process whereby water is replaced by minerals. This process begins rapidly and reaches 70% of maximum density after a few days (Parfitt, 1990), then continues slowly for some months. Quiescence then follows, in which osteoblasts convert to mature bone cells, osteocytes (Martin & Burr, 1989). In both compact and trabecular bone this process normally takes approximately three to six months to complete (Dalsky, 1989; Frost, 1988). Usually 20% of trabecular bone and 5% of compact bone are in active remodelling at any one time (Dalsky, 1990). Trabecular bone is far more sensitive to rapid bone turnover leading to remodelling rates being greater in the axial skeleton (Martin & Burr, 1989). This is due to the greater surface area of trabecular bone (Snow-Harter & Marcus, 1991).

The activation rate of remodelling is dependent on age, gender, physical activity and bone type. In healthy, well nourished juveniles and infants new bone formation proceeds more rapidly than resorption. There is a net bone gain. The high rate of activation is attributed to growth hormone activity (Martin & Burr, 1989). Resorption is necessary for attainment of normal bone contours, maintenance of marrow cavities, provision of channels for passage of nerves and blood vessels, and release of calcium to extracellular fluids (Martin, 1985; Parfitt, 1990). The body will acquire and

adjust the amount and placement of bone tissue necessary for life during this period.

The coupling of resorption and formation determine the rate of bone loss (Dalsky, 1990). Adults go through a period during which bone mass and mineral content tend to stabilize and remodelling is mainly for mineral homeostasis and repair. Greater resorption than formation leads to an overall bone loss. This is generally referred to as age related osteoporosis (Eisman, 1991). Compact bone becomes thinner in appearance and trabecular bone becomes very sparse with gaps appearing between the horizontal linkages (Ellerington & Stevenson, 1992). Osteoporosis is a condition in which bone tissue is lost, however the bone tissue that remains is normally mineralized (Eisman, 1991). This process occurs in both men and women as they age, however post-menopausal women are prone to a greater loss due to hormonal changes (Oyster *et al* ., 1984). Normal age related bone loss is associated with a disparity in the rates of resorption and formation. There is also an age related loss of osteoblastic activity due to a decline in the number of stromal cells (Parfitt, 1990).

The osteogenic response is largely determined by the amount of stress or strain that is placed on the tissue . Genetic phenotype will determine the major skeletal features, such as distribution of cortical and trabecular bone (Lanyon, 1992) but the architectural adaptations of the skeleton will be a result of the dynamic loads and strains experienced during life (Frost, 1988). Results from animal experiments have shown the importance of load bearing in the formation of bone tissue. Rubin and Lanyon (1984) in a series of studies on avian ulna preparations demonstrated that in birds with zero loads applied there was a loss in bone mineral content of 18% in a six week period. Birds that were subjected to 4 loading cycles a day (8 seconds) showed virtually no remodelling while birds subjected to 36 cycles per day (72 seconds) showed a large increase in bone mineral content up to 143% of the original bone mineral content value. There was no significant difference in bone mineral content in birds subjected to 360 cycles per day (12 minutes) or 1800 cycles per day (60 minutes) than those birds subjected to 36 cycles per day.

The result from disuse is predictable. Studies on immobilization and bed rest have produced similar results (Dalsky, 1990). The results obtained from the birds subjected to varying load cycles however suggests short dynamic loading is able to produce an osteogenic response equally as effective as longer repetitive activity (Rubin & Lanyon, 1984). Frost (1988) however discusses the need for a threshold intensity to act as a stimuli and calls this

the "minimum effective strain". The proposal is that strains greater than the minimum effective strain would lead to a change in the architecture of the bone tissue, whilst strains less than this threshold would lead to a reduction in the response (Frost, 1988). It is hypothesized that there is a strain related increase in the number of osteocytes showing glucose 6 phosphate dehydrogenase activity, which is implicated in RNA synthesis, implying increased bone formation (Lanyon, 1992).

Repetitive loading or exercise is not consistent with large gains in bone tissue (Frost, 1988). Frost (1988) makes the point that marathon runners, who indulge in very large amounts of repetitive activity are generally slight in build, while weight-lifters are relatively massive. Skeletal adaptations may well be enhanced by short, intense, diverse strains rather than repetitive normal strains (Lanyon, 1992). As Lanyon (1992) states

"the most osteogenic response to loading is produced by high strains, high strain rates and unusual strain distributions. ... Short periods of diverse weight-bearing exercise will be far more effective therefore than long periods of running or bicycling".

2.2.3 Importance of Calcium.

Calcium is an extremely important ion involved in a number of cellular activities. Muscle contraction is dependent on the release of calcium (Jones & Round, 1990), as well as processes such as blood clotting, cell division, secretory processes, membrane integrity, intra-cellular communication, neuro-transmission and bone mineralisation (Heaney, 1990). Plasma calcium concentration is maintained within narrow limits (1.1 - 1.3 mMol/l, Murray, Granner, Mayes & Rodwell, 1990). There is little tolerance for deviation, with problems being experienced with both increases (muscle paralysis) and decreases (tetanic contractions) in calcium plasma concentration (Murray *et al* ., 1990). Ninety nine percent of the body's calcium is stored in the skeleton where it provides the inorganic structural component of bone. The plasma calcium levels however are independent of bone calcium. The importance of calcium homeostasis is shown by the fact that bone calcification will be sacrificed to maintain plasma levels.

Parathyroid Hormone (PTH) and Calcitonin (CT) are two hormones involved in the regulation of calcium. PTH is synthesized and secreted by the parathyroid gland in direct response to blood calcium levels. It has a number of effects, all designed to increase plasma calcium. If the plasma calcium levels are low, (hypocalcaemia) PTH will be released, promoting osteoclastic action thereby mobilizing calcium from bone tissue (Hardy,

1981). PTH also facilitates reabsorption of calcium from the kidney and regulates the conversion of Vitamin D to 25-hydroxy-vitamin D (25-OH-D) in the liver and further to 1,25-dihydroxyvitamin D ($1,25\text{-}(OH)_2D_3$) in the kidney (Lamberg-Allardt, 1991), which stimulates intestinal absorption of calcium (Martin, 1985). CT which is released from the thyroid gland in a situation of hypercalcaemia, opposes the action of PTH (Martin, 1985). There is some evidence that osteoclasts retract from the bone surface they are currently acting on in the presence of CT (Martin, 1985) thereby inhibiting calcium release from bone. CT secretion is reduced with age while PTH secretion increases (Shepherd, 1987; Martin, 1985). CT is also released prior to food intake. The theory is that the increase in CT decreases the rate at which mineral is transferred from bone to plasma thereby maintaining low calcium levels as food is absorbed from the intestine (Martin, 1985).

2.2.4 Dietary Calcium.

With no clear evidence of a positive effect of a high calcium intake on bone mineral density, attention to dietary calcium is being promoted (Marcus, 1987). The recommended daily allowance (RDA) of calcium is however not firmly established. American RDA for perimenopausal women is 1000 mg/day with the World Health Organization having an RDA of 500 mg/day (Heaney, 1988). In Australia the RDA is 800mg/day for pre-menopausal women and 1000mg/day post-menopausal women (Angus *et al.*, 1988)

A number of studies have shown no correlation between calcium intake and bone mineral density. Mazess and Barden (1991) in a two year study involving premenopausal women found calcium intake had no influence on bone mineral density. Similarly Riggs, Wahner, Melton, Richelson, Judd and O'Fallon (1987) in a study measuring dietary calcium intake and rates of bone loss in women aged 23 - 84 found no significant correlations. A study of Australian women aged 23 - 75 years produced similar results (Angus *et al.*, 1988). Kroger, Kotaniemi, Vaino and Alhava (1992) in a study of Finnish children, aged 6 - 19 years also found no correlation between estimated calcium intake and bone mineral density. In contrast however, dietary calcium was found to be linked to bone mineral density in a study of young female athletes (Wolman, Clark, McNally, Harries & Reeve, 1992).

Cross-sectional studies however may not offer a true picture. Measuring or estimating calcium intake at 40 years offers no accurate assessment of the diet during adolescence. In the well known study of two Yugoslav villages whose inhabitants differed in dietary calcium intake, bone density was significantly higher in young people from the high calcium intake village (Matkovic, Kostial, Simonovic, Buzina, Brodarec & Nordin, 1979). More recently, a study on historical milk consumption by post-menopausal women has found a relationship between bone mineral density and milk consumption during childhood (Sandler, Slemenda, LaPorte, Cauley, Schramm, Barresi & Kriska, 1985). This study however relied on subjects

recalling eating habits of decades ago which may not be entirely accurate (Martin & Houston, 1987).

There are 3 major factors which may contribute to calcium deficiency: intake, absorption and excretion. The calcium content of the skeleton at birth is approximately 25 g which steadily increases to approximately 800g at age 17 years for a female (Heaney, 1990). This growth of the skeleton, particularly during adolescence requires a calcium retention of 160 mg/day with requirements of 350 mg/day retention during growth spurts (Heaney, 1990). Thus, with a 35% gut absorption of calcium for an adolescent the RDA for calcium should be in excess of 1200 mg/day during adolescence (Heaney, 1990).

Intestinal absorption of calcium is relatively inefficient (Heaney, 1990). Calcium demand is at its highest during adolescence, but the absorption efficiency will only be in the range of 30-45% (Heaney, 1990). In an adult the efficiency varies, but will be approximately 30% (Heaney, 1990). Absorption efficiency is inversely related to intake, but Heaney (1990) makes the point that low absorption from a high intake will still produce more calcium than high absorption from a low intake. eg 100% absorption of 200 mg is less than 15% of 2000 mg.

Caffeine and antacids can affect absorption as well as the sex hormone, estrogen. Heaney (1990) states that estrogens enhance calcium absorption and decrease urinary losses , whereas others suggest that this may not be the case, but rather that estrogen reduces intestinal secretion of calcium and therefore reduces excretion of fecal calcium (Martin, 1985). Antacids, diets high in protein and high sodium intakes are associated with increased urinary calcium loss. Estrogens have also been linked with increased levels of 1,25-$(OH_2)D_3$, which is involved in intestinal absorption of calcium. The suggestion is that estrogen enhances the activity of the enzyme involved in converting vitamin D to 1,25$(OH_2)D_3$ (Martin, 1985). What is definite is that calcium absorption decreases with age (Smith & Gilligan, 1989), partly due to falls in vitamin D levels from reduced solar exposure, dietary deficiencies and reduced secretion of CT (Heaney, 1990).

Post-menopausal women are the group most at risk. There is an increase in skeletal remodelling with greater movement of calcium out of the bone tissue (Lindsay, 1990). Aligned with this is less intestinal absorption and greater urinary loss of calcium, which will further promote secretion of PTH. The greatest loss of bone tissue occurs at trabecular sites with losses in the vertebrae often exceeding 35% (Lindsay, 1990) during the first five years after menopause (Dawson-Hughes *et al.*, 1993).

2.2.5 Attainment of Peak Bone Mass.

The amount of bone tissue in adults is a function of the peak bone mass achieved and the subsequent rate of bone loss (Eisman *et al.*, 1993). The generally accepted and traditional model is that peak bone mass occurs by approximately 35 years of age (Bonjour, Theintz, Buchs, Slosman & Rizzoli, 1991; Dhuper, Warren, Brooks-Gunn & Fox, 1990). Recent evidence however suggests that the first two decades of life may be the most important for maximizing peak bone mass.

The onset of puberty is associated with an increase in bone mineral density. In a study of normal caucasian children aged 1 - 15 years, puberty was associated with an increased bone mineral density of the lumbar spine (Glastre, Braillon, David, Cochat, Meunier & Delmas, 1990). In this study the mean bone mineral density of 15 year olds was twice that of the 2 year olds. The mean bone mineral density of the spine was estimated to be approximately 14% lower than the values of young adults. Bonjour *et al.* (1991) found similar results in that the onset of puberty was associated with increases in bone mass. In contrast to Glastre *et al.* (1990), Bonjour *et al.* (1991) found that females had achieved peak bone mass in lumbar 2 - 4 (L2 - L4) and the femoral neck by age 14 - 15 years when these values were compared with data from adults, aged 20 - 35 years. Results from Kroger *et al.* (1992) suggest that peak bone density of the femoral neck in females may

be attained by the early twenties. In general support of these studies are the results from a study measuring bone mineral density in L2 - L4 of subjects aged from 3 - 30 years (Gordon, Halton, Atkinson & Webber, 1991). The authors report no further increases in lumbar spine mass after puberty. Results by Geusens, Cantatore, Nijs, Proesmans, Emma and Dequeker (1991) support the attainment of peak bone mass by late teens or early twenties. This study of subjects aged between 3 - 25 years found lumbar spine and distal radius bone mineral density in females reached its peak between age 16 - 20 years. Gilsanz *et al.* (1988) compared peak trabecular vertebral density between adolescent and adult females. This group concluded that trabecular vertebral density reached its peak during adolescence, at the time of the end of longitudinal bone growth.

Bone mass is dependent on a number of variables. Males generally achieve higher values than females and blacks are reported to have higher values of bone mineral density than caucasians (Matkovic *et al .,* 1993). Nelson *et al.* (1993) however compared skin colour and bone mineral density of post-menopausal women and found no significant differences. The mechanism for race differences is unknown.

Genetic influences are considered to be a major determinant of an individual's potential bone mineral density (Kelly *et al.,* 1990). The relative importance of heredity in relation to environmental factors is however

unclear. Krall and Dawson-Hughes (1993) studied 40 families which included a post-menopausal mother, a pre-menopausal daughter, a father and a son. The authors estimated that heredity was responsible for 46 - 62% of bone mineral density but concluded that environmental or lifestyle factors can make a substantial impact on the achievement of peak bone mass. Kelly *et al.* (1990) reported on a number of studies that have attributed genetic influences to contribute up to 80% of bone mineral density variance. Mazess and Barden (1991) in a two year study of pre-menopausal women aged 20 - 39 years measured smoking, birth-control pills, dietary intake and physical activity and concluded that bone mineral density is largely determined by genetic influences. This study did however find that smokers had significantly lower spine bone mineral density. These data are supported by a study by Slemenda *et al.* (1989) in which 84 women were studied over 3 years. Heavy smokers were found to have significantly lower radial and spine bone mineral content than light or non-smokers. A Swedish study of 70 year old men found tobacco smokers to have lower bone mineral content and muscle strength than non-smokers of the same age (Mellstrom *et al* ., 1982). In contrast, an Australian study found no significant differences in bone mineral density between smokers and non-smokers (Pocock *et al.*, 1989). The authors however discuss the possibility that a smoking lifestyle may cause a decrease in physical activity and an increase in alcohol consumption, factors which were not evident in their study.

Excessive alcohol consumption has been associated with low bone mineral density. Johnell *et al.* (1982) measured bone mineral content in alcoholic men and found a significant difference between the alcoholics and age matched controls. It is unlikely however that moderate alcohol consumption has a deleterious effect (Eisman, 1991).

2.2.6 Hormonal Status.

The major reason why post-menopausal women experience accelerated bone loss is the cessation of ovarian estrogen secretion (Nuti & Martini, 1993; Arnaud, 1993). Conversely, the onset of puberty is associated with increases in bone mineral density. The influence of hormonal status is obviously strong. In a study of females aged 13 - 20 years subjects with lower estrogen levels," based on physiological events known to reflect circulation estrogen levels" (Dhuper *et al.*, 1990) had lower spine and wrist bone densities than those girls with higher scores (Dhuper *et al* ., 1990).

The relationship between oral contraceptives and bone mineral density is not conclusive. Mazess and Barden (1991) found no relationship between pill use and bone density while Lindsay, Tohme and Kanders (1986) found a 1% increase in vertebral bone mineral density for each year of pill use. in young women aged 25 - 35 years.

The mechanism of estrogen protection of bone is not fully understood. Ellerington and Stevenson (1992) discuss the possibility of a link between estrogen and calcitonin, which is an osteoclast inhibitor. Calcitonin levels are known to fall after menopause. Estrogens may also block the production of specific cytokines, that are stimulators of bone resorption (Arnaud, 1993). Recent evidence of estrogen receptors on bone cells may also present a mode of action (Christiansen & Lindsay, 1990; Ellerington & Stevenson, 1992).

Other hormones affecting bone metabolism are the glucocorticoids and growth hormone. Growth hormone increases the rate of bone remodelling as well as enhancing intestinal and renal absorption of calcium (Hardy, 1981). Large amounts of cortisol depress bone formation by increasing the ratio of osteoclasts to osteoblasts (Hardy, 1981) and increase secretion of PTH (Reid, 1989). Glucocorticoids also depress intestinal and renal absorption of calcium possibly through direct action as cortisol has been shown to decrease levels of calcium binding protein in the chick intestine with the same protein being found in the kidney (Reid, 1989). Vitamin D metabolism may be indirectly affected via PTH, as levels of $1,25(OH)_2D_3$ have not been found to decrease with short term glucocorticoid infusion which resulted in reduced calcium absorption (Reid, 1989).

2.2.7 Body Composition

Females characteristically have greater fat content and smaller muscle mass than do males (Vogel & Friedl, 1992). The reference female at age 18 years has a fat content of 26 - 28%, with reference male approximately 14 - 18% (Vogel & Friedl, 1992; Frisch, 1990). The amount of body fat in the female body is important as too much or too little can cause reproductive problems.

Adipose tissue may directly affect fertility. Conversion of estrogen from androgens occurs in adipose tissue and this source is particularly important for the post-menopausal female (Frisch, 1990). Body weight influences the 'potency' of estrogen with very lean females increasing the amount of 2-hydroxylated form of estrogen which has low affinity for estrogen receptors (Frisch, 1990). Obese females, by contrast, decrease the amount of 2-hydroxylated estrogen but produce greater amounts of 16-hydroxylated estrogen which is very potent (Frisch, 1990). Higher body weights are generally associated with denser bones (Dawson-Hughes *et al* ., 1993) but very lean athletes may have normal body weight with low fat levels, as muscle mass is relatively heavy (Frisch, 1990). Amenorrhea, the cessation of regular ovarian cycles, is associated with females possessing a low percentage of body fat (Frisch, 1990). Indeed, the onset of menstrual cycles will not occur until a female has attained a minimum weight (Frisch, 1990). Pre-pubertal body composition of lean mass to fat is 4:1, whereas after puberty the ratio is

in the order of 3:1 (Frisch, 1990). As androgens are able to be converted to estrogens in adipose tissue, body composition in females can be an important factor in the maintenance of bone mineral density.

2.3 The Muscular System.

2.3.1 Introduction.

Muscle fibres are comprised of a number of structural proteins, together with the contractile proteins of actin and myosin organized into units called sarcomeres. There are three major types of skeletal muscle fibre. Type 1 fibres have a large number of mitochondria, and are fatigue resistant. They have a high capacity for aerobic metabolism (Powers & Howley, 1990). Type 11b fibres are rich in glycolytic enzymes, have high force production but are rapidly fatigued (Noth, 1992). The third type of fibre is intermediate in nature and is known as Type 11a (Noth, 1992). A human muscle typically contains all three fibre types but their distribution is scattered and their proportions variable (Henriksson, 1992).

The number and type of fibre is determined by genetic inheritance (Wilmore, 1991). The muscle mass of a newborn child is 20% of body weight (Israel, 1992) increasing to 40% or greater, dependant upon training. High force demands will cause hypertrophy, an increase in the cross-sectional area

and density as a result of increased fibre size (MacDougall, 1992), whilst reduced use will cause atrophy (Israel, 1992).

2.3.2 Effects of Age.

Buskirk and Segal (1989) report that older women have greater difficulty than older men in performing work associated activities such as lifting or carrying loads. They note that approximately 24% of elderly people had difficulty with heavy housework, with retired people experiencing greater problems than the employed. Heavy housework obviously requires muscular strength and endurance. Major changes in muscle strength and function may however be possibly attributed to disuse rather than the natural age related losses (Wilmore, 1991). Age related losses do occur which cannot be regained, but a sedentary lifestyle will compound these losses into a premature loss of function (Wilmore, 1991).

The strength of muscle is proportional to the cross-sectional area of muscle (Wilmore, 1991). Slow twitch fibres are typically smaller in diameter than fast twitch fibres and the motor unit posses fewer fibres (Billeter & Hoppeler, 1992). Increases in the strength of the muscle arise from hypertrophy of the contractile components of the muscle. Neuro-endocrine control regulates the development of muscle fibres, and the adaptations depend upon the stimulus received (Kraemer, 1992 (a)). Growth hormone (GH), insulin-like

growth factors (IGFs) which mediate the action of GH (Florini, 1987) and testosterone are the primary anabolic hormones involved in the growth of muscle tissue (Kraemer, 1992 (a)). Secretion of GH increases with resistance exercise and positively influences protein synthesis (Kraemer, 1992 (b)). Testosterone, a predominantly male hormone, can also have a positive effect on protein synthesis (Florini, 1987). Muscle strength peaks at approximately 30 years of age, is maintained to 50 years and then decreases (Shepherd, 1987). Power, involving both strength and speed also declines due to changes within the central nervous system (Buskirk & Segal, 1989). Total muscle mass decreases with age, with an accompanying decrease in individual muscle size (Wilmore,1991) due to atrophy of fibres, particularly Type 11 (Hopp, 1993).

Wilmore (1991) reports that the cross-sectional area of the quadriceps of healthy men in their seventies was 25% smaller than men in their twenties, with isometric strength of the quadriceps 39% lower. Studies targeting muscle groups used for daily activities such as ankle plantar or dorsiflexion however have shown little decline in strength (Wilmore, 1991). It may be that a loss of function is dependent on usage patterns .

Loss of strength, power and size of muscle can reflect a loss of actual muscle fibres (Wilmore, 1991), discrete motor units or the number of fibres innervated by a motor unit (Hopp, 1993). Lexell, Henriksson-Larsen,

Wimblad & Sjostrom (1983) autopsied 12 previously healthy men, 6 of whom were aged 19 - 37 years and 6 who were between 70 - 73 years. They found the size of the muscles of the older group were 18% smaller and that the total number of fibres was 25% less when compared to the younger group. There was a greater loss of fast twitch fibres than slow twitch fibres. Young, Stokes and Crowe (1984) found decline in quadriceps strength proportional to the decrease in muscle size. Fibre numbers may decrease due to impaired repair mechanisms, or from central denervation, ie lack of innervation from motor units (Buskirk & Segal, 1989). This suggests there is no actual difference in aged muscle, but rather there is less of it, resulting in decreased strength (Buskirk & Segal, 1989).

Increasing evidence demonstrates a reduction in the number of motor neurons that innervate muscle (Wilmore, 1991; Oertel, 1986; Hopp, 1993) possibly as a result of aging (Jones & Round, 1990). Animal studies have shown reductions in the number of motor neurons, particularly the large alpha neurons in a given motor unit as well as a 40 - 75% decrease in the number of motor units (Doherty, Vandervoort & Brown, 1993; Oertel, 1986; Hopp, 1993). The surviving motor units however are larger, as denervated muscle fibres are reinnervated by surviving motor units, increasing their functional field (Doherty *et al.*, 1993). This may be responsible for the greater loss of anaerobic power with no apparent reduction in oxidative capacity in the aged (Buskirk & Segal, 1989), as most decrease is evident in fast type IIb

fibres which are innervated by large alpha neurons. There may also be reduced capacity to supply acetyl choline at the neuro-muscular junction over the new extended area (Doherty *et al.*, 1993). An increase in the number of muscle fibres staining for type I myosin has also been found which may provide evidence of a fast to slow conversion following reinnervation (Doherty *et al.*, 1993) as the contractile properties of the muscle fibre are determined by the neural supply (Jones & Round, 1990). Functionally, aged muscle is less robust and will fatigue more readily (Buskirk & Segal, 1989). Studies into aerobic metabolism have shown less mitochondria and cyctochrome c, a vital link in energy production, in rats, mice and humans. Coupled with this is a reduced cardiovascular capacity for oxygen delivery. Therefore aged muscle, with less fibres, less motor units and a reduced metabolic capacity has a diminished potential to sustain high intensity work (Buskirk & Segal, 1989).

2.4 Effects of Exercise.

2.4.1 Introduction.

Exercise has been positively correlated to bone density (r=0.5) (Jonsson *et al .*, 1992; Jacobson, Beaver, Grubb, Taft & Talmage, 1984; Rikli & McManis, 1990). It is suggested that exercise is an important preventative factor for

osteoporosis, and is possibly implicated in maintenance of bone density in older people (Rikli & McManis, 1990; Dalsky, 1987). Similarly, loss of muscle strength occurs with age, but aging athletes record higher values for strength than do sedentary counterparts (Wilmore, 1991; Noble, 1986).

Remaining physically active appears to be an important strategy for enhancing the quality of life. Aging may cause a decrease in many physical capacities but it appears that exercise can reduce the effects. Maintaining an active lifestyle, or participation in training has a positive effect on muscle and bone. Shepherd (1987) reports a number of studies in which regular , moderate exercise has shown improvements in both muscular strength and endurance. The rate of response however, is slower than in younger people. Wilmore (1991) details studies in which anaerobic and aerobic capacities improved due to training programmes.

2.4.2 Muscle Strength and Exercise.

Dummer,Vaccaro and Clarke (1985) found female Masters swimmers had decreased strength compared to younger athletes, but their average values were higher than untrained peers. Clarke, Hunt and Dotson (1992) found muscular strength and endurance in men decreases with age, but not until the age of 50 is there an overall decline. Importantly, all active subjects had greater muscle strength than inactive subjects at all ages tested. Active

training however does not appear to prevent deterioration. Pollock, Foster, Knapp, Rod and Schmidt (1987) completed a 10 year study on Master runners and found the group who maintained their training schedule maintained their aerobic capacity whilst the group who reduced their training showed a decrease. Surprisingly, all runners lost muscle mass, particularly in the upper body. Interviews determined that most of the runners only trained aerobically and did little strength training. Three of the 25 subjects who maintained muscle mass used some strength training, therefore age related loss of muscle strength may be reduced by regular, moderate physical exercise (Pollock *et al* ., 1992).

2.4.3 Exercise and Bone Mineral Density.

Exercise in general has been found to have a positive relationship with bone mineral density. Jacobson *et al.* (1984) confirmed this relationship with results that showed the bone density, measured at a site related to the position where the radius and ulna are separated by 5mm (trabecular), the lumbar vertebrae (trabecular) and first metatarsus (cortical) of older athletic women was greater than that of sedentary subjects. Rikli and McManis (1990) found that post-menopausal subjects, measured at the 1/3 distal location radius maintained bone mineral content during a 10 month exercise programme, in contrast to control subjects who lost bone mineral content during the same time span. Oyster *et al* . (1984) found that exercise can act as

a deterrant to osteoporosis, with increases in bone mineral density, measured at the second metacarpal (cortical diameter), after an exercise programme in post-menopausal women. Peterson, Peterson, Raymond, Gilligan, Checovich and Smith (1991) report that middle aged women participating in an endurance dance programme increased muscle strength but with no significant increase in bone mineral density. A number of sites were measured in this study; lumbar spine, proximal femur, radius, ulna and humerus. Explanations given for these results are that the effects of exercise on bone mineral density may have already occurred prior to the study, as subjects were already participants in an exercise class. Wolman, Faulmann, Clark, Hesp and Harries (1991) found that elite runners had significantly higher bone density in the femoral shaft than did rowers. Interestingly, elite dancers and controls had similar levels.

As adolescence is an important stage in the acquisition of bone mass it is reasonable to assume that physical activity during those years will maximize peak bone mass. Katzman, Bachrach, Carter and Marcus (1991) measured the acquisition of bone mineral in pre-pubertal and pubertal girls and correlated these values with exercise. Exercise habits were determined by questionnaire and subjects were assigned to one of three groups. High activity was considered to be more than three sessions of 30 minutes activity, moderate activity was two to three sessions and low activity, less than two sessions weekly. The authors report no correlation between bone mineral

accumulation and exercise. It should however be noted that there was no attempt to quantify the intensity of the exercise nor if the exercise was weight-bearing or non-weight-bearing. In contrast, Kroger *et al.* (1992) in their study of Finnish children aged 6 - 19 years found a positive relationship of bone mineral density to exercise. Children who participated in sports regularly over five hours per week had significantly higher bone mineral density of the femoral neck compared to less active subjects. The sports mentioned in this study were ice-hockey, football, basketball, volleyball, jogging, athletics which are all weight bearing activities.

Kriska, Sandler, Cauley, LaPorte, Hom and Pambianco (1988) attempted to assess childhood activity with adult bone measurements. They hypothesized that if physical activity is positively associated with accumulation of bone mass a lifetime of physical activity should be reflected in adult bone values. Subjects were asked to estimate the number of hours spent and the type of activity for four time periods (14 - 21, 22 - 34, 35 - 50 and 50+ years). The activity was then converted into kilocalories, depending on the estimated intensity. The authors considered their estimation instrument to have reasonable reliability and validity. Results of this study demonstrated a significant relationship between bone mineral density and historical activity but the correlations are weak (r=0.17).

McCulloch *et al.* (1992) compared differences in the bone density of the os calcis and the bone mineral content of the distal radius between subjects aged 13 - 17 years. The subjects were divided into three groups: swimmers, soccer players and controls. The athletic subjects were considered to be elite and the controls did not regularly participate in any physical activity. The soccer players had a higher bone density in the os calcis than the controls and the swimmers although this trend was not statistically significant. When the dynamics of the activities are considered this trend is predictable. Soccer is a weight-bearing activity whilst swimming, although strenuous, involves little load bearing. This study showed little difference in bone mineral content of the distal radius between the groups. Swimming does involve upper limb work, but once again is not weight-bearing. Therefore encouraging children to participate in exercise, particularly during adolescence may be an important strategy in dealing with osteoporosis.

2.4.4 Relationship of Bone Mineral Density with Muscle Strength.

In a number of studies, muscle strength has been found to hold a positive relationship with bone density (Bevier, Wiswell, Pyka, Kozak, Newhall & Marcus, 1989; Jonsson *et al.*, 1992; Snow-Harter *et al.*, 1990). This is a predicted relationship as mechanical stress is one of the factors that determines the rate of bone remodelling. Snow Harter *et al.* (1990) found significant relationships between the strength of specific muscle groups and bone

mineral density (r=0.5). Grip strength proved to be a predictor of midradius bone density as well as lumbar spine density. Reasons suggested for this relationship are that the trunk stabilizing muscles that are involved during arm activity would exert direct forces on the hip and spine (Snow-Harter *et al.*, 1990).

Jonsson *et al.* (1992) found active subjects had greater quadriceps strength and greater bone mineral content of the radius than the sedentary controls. In the same study bone loss was greater in post-menopausal women but the apparent decrease was smaller in active women. Bevier *et al* . (1989) found significant, but quite low correlations (r=0.3) between grip strength and mid-radius bone mineral density. In women, weight and grip strength were able to predict spine bone mineral density suggesting that body mass may effect bone density. Kyllonen *et al.* (1991) found a significant correlation between lumbar spine bone mineral density and back muscle strength in healthy post-menopausal women. In osteoporotic women versus normal women back extensor strength was significantly lower in the osteoporotic women (Sinaki *et al.*, 1993). The authors' conclude that the reduced back strength may contribute to osteoporosis. Historical physical activity in this study was not considered although present activity was scaled into three categories: housework, job and sport. The normal women had a greater total physical activity score in all age groups studied but were only significantly different in one age group: 40 - 59 years. It would be interesting to research historical

physical activity in this group during adolescence. Possibly lack of physical activity while young contributed to the present situation of poor back strength and osteoporosis.

2.4.5 Type of Exercise.

There is some indication that exercise that is weight-bearing is more beneficial for bone health than non-weight-bearing activities (Rikli & McManis, 1990; Block *et al.*, 1989; Dalsky, 1987; Peterson *et al.*, 1991; Heinrich, Going, Pamenter, Perry, Boyden & Lohman, 1990). Lack of weight-bearing activity from prolonged bed rest has been found to result in decreased bone density (Dalsky, 1987).

Nilsson and Westlin (1971) found the highest bone density in weightlifters followed by throwers, runners, soccer players and lastly swimmers. They did not however find any correlation between muscle strength (quadriceps force) and bone density (distal end of femur). They noted however that there was increasing bone density of the leg with increasing load taken on the lower limbs within the group of athletes. The swimmers bone density (0.226 g/cc) although the lowest of the athletic group was still higher than that of the non-exercising controls (0.168 g/cc) (Nilsson & Westlin, 1971). Orwoll *et al.* (1989) however discovered that older male swimmers had a significantly higher vertebral bone mineral density (123 mg/cm^3) than non-exercisers

(108 mg/cm3), but there was no difference in the vertebral bone mineral density of older female swimmers (129 mg/cm3) and non-exercisers (127 mg/cm3). Orwoll *et al.* (1989) attempted to explain the differences between the male and female results by suggesting that muscular forces generated by the male swimmers were greater than those generated by the female swimmers and so the males experienced greater skeletal remodelling.

Block *et al.* (1989) found that male athletes (water polo and weight trainers) had 18% and 9% greater bone mineral density at the spine and hip respectively than non-exercisers. Contrary to previous studies, they found no significant differences in bone mineral density between the water polo players and those involved in weight training. They did however caution interpretation that a non-weight-bearing activity such as water polo would have such a positive effect on bone mineral density as the subjects were elite competitors with components of aerobic and heavy resistance work in their training programmes.

In the study of male and female adolescent athletes by McCulloch *et al.* (1992) as previously mentioned , bone mineral density in the os calcis (foot; trabecular) was greater in soccer players, secondly in the control group and lastly in swimmers. McCulloch *et al.* (1992) concluded that weight-bearing activities such as running may be more beneficial to the axial skeleton than non-weight-bearing activities such as swimming. Using elite athletes and

performers Wolman *et al.* (1991) found runners who do intense weight-bearing exercise by running up to 70 miles per week had the highest bone density of the femoral shaft compared to rowers second, and then dancers. Dancing is a weight-bearing activity but Wolman *et al.* (1991) discusses the point that much of their work is slow and controlled with less than 10% jumping. Rowing is non-weight-bearing but weight training of the legs is involved in the training regime. The suggestion is made that intense exercise may cause a greater effect on bone density than moderate work. This is further backed up by Stillman, Lohman, Slaughter and Massey (1986) findings for which there was a higher bone mineral content of the ulna and radius in women who had a high level of physical activity. No difference was found between the moderate and low intensity groups.

Jacobson *et al.* (1984) report bone mineral density was greater in female athletes with a range of age from 22 - 70 years than age matched non-exercisers. The major finding was differences between the controls and athletes in the 50 - 70 year old group: post-menopausal. Distal radial bone mineral density for athletes was higher (975 g/cm^3 $x10^{-3}$) compared to the non-exercisers (790 g/cm^3 $x10^{-3}$) with $p < 0.001$. They conclude a decrease in bone mineral density was not apparent in the 50 -70 years group of female athletes, with less than 20% of them on hormone replacement therapy. It was stated that some (?) of the subjects in this study were swimmers, but that they had considerable involvement in weight-bearing activity.

Results of a study by Heinrich *et al.* (1990) indicate that weight training exercise in females may have a more positive effect on bone mineral content than running or swimming. Interestingly, the swimmers' lumbar bone mineral content was not less than the lumbar bone mineral content of the runners. This study also discusses a relationship between bone mineral content and body composition. They hypothesize that if there is a greater fat-free body weight, ie more muscle, greater muscular force will be exerted on the skeleton thus providing a positive stimulus for bone.

The results from Kriska *et al.* (1988) show a very weak correlation between historical physical activity and adult bone parameters. This study did not however take into account the different types of activity when estimating intensity. Subjects with historical non-weight-bearing activities may well have different results compared to historical weight-bearing activities.

Grove and Londeree (1992) report results from a study of post-menopausal women participating in low and high impact activities for a year. Control subjects experienced a decrease in bone mineral density while the active subjects maintained bone mineral density . There was no significant difference between the high impact and low impact groups. High impact exercise was exercise that produced ground reaction forces of greater or equal to 2 times body weight. Low impact was exercise that produced ground reaction forces of equal or less than 1.5 times body weight (Grove &

Londeree, 1992). The authors discussed the possibility that 1.5 times body weight may be enough to maintain bone mineral density but the high impact exercise may not be of sufficient intensity to increase bone mineral density. This group of subjects were however post-menopausal without the protecting effects of estrogen.

2.4.6 Specific Sports.

Netball is a weight-bearing game characterized by short intense bursts of play with numerous stops and sudden changes of direction. It uses high leaps to receive or intercept passes and has been associated with a high potential for injury (Steele & Milburn, 1987). Many netball games are played on hard surfaces such as bitumen leading to little impact force being absorbed by the surface (Steele & Milburn, 1987).

In a study by Steele and Milburn (1987) subjects were asked to perform a typical netball movement: run forward, 'break' to a side, catch, land and pivot then pass to another player. They landed on a force platform and the ground reaction forces were measured. Results from this study indicated ground reaction forces ranged from 3.9 - 4.3 times body weight for the dominant leg and 4.2 - 4.6 times body weight for the non-dominant leg. Running, by contrast, has been found to produce ground reaction forces of 2 - 3 times body weight (Cavanagh and LaFortune, 1980). In older athletes

running did not stop bone loss but regular runners had significantly less bone loss than controls (Michel, Lane, Bjorkenfren, Bloch & Fries, 1992). Field hockey is a game played predominantly on a large pitch of grass. Players do not generally leap but remain low to the ground. To my knowledge there are no studies measuring ground reaction forces experienced by field hockey players, but characteristics of the game would indicate similar results to running.

Swimming is an activity in which the effects of gravity are minimised (Swissa-Sivan, Azoury, Statter, Leichter, Menczel & Samueloff, 1991). The adaptability of mature rat bone mineral density to chronic swimming exercise was assessed by Swissa-Sivan *et al.* (1991). This group found that swimming exercise exerted a positive influence on the development of bone mineral density in mature rats. They theorised that the resultant changes were due to the action of contracting muscle on the bones. Another study measuring the effect of swimming exercise on rats however found different results (Bourrin, Ghaemmaghami, Vico, Chappard, Gharib & Alexandre, 1992). Young rats exercising for up to 6 hours per day for 5 weeks experienced bone tissue loss in the lumbar vertebrae (24.7%) and distal femur (15.2%) (Bourrin *et al.*, 1992). The authors suggest the rats may have overtrained or the study length was not sufficient, therefore not allowing endurance adaptations to occur. This study also suggests the importance of gravity and weight-bearing in the development of bone mineral density.

2.5 Bone Densitometry.

2.5.1 Introduction.

Bone densitometry is a non-invasive means of determining the bone mineral content and density of the skeleton. There are 4 major techniques commonly used today: single-photon absorptiometry (SPA), dual-photon absorptiometry (DPA), dual-energy X-ray absorptiometry (DEXA) and quantitative computed tomography (QCT) (Schmitz, Djukic & Genant, 1990). A brief discussion on each follows. Precision refers to the standard deviation of repeated measurements expressed as standard error, while accuracy is the reliability that the value reflects the true mineral content (Schmitz *et al.*, 1990).

Radiation damage to cells is determined by the amount of energy absorbed per unit of time. The absorbed dose is known as the gray (Gy) which is equal to one joule per kilogram and is dependent on both the type of energy and the type of material absorbing it (Hart, Mazzolini, Tytler & Callahan, 1991). The dose equivalent however is a more useful measure as different parts of the body absorb varying amounts of radiation, and different types of radiation have varying powers of penetration (Hart *et al.*, 1991). The dose equivalent takes into account the differing amount of harm caused by the same number of grays from different types of radiation. The standard unit

for dose equivalent is the sievert (Sv) which is the absorbed dose multiplied by a quality factor. The quality factor being dependent on the type of radiation (Hart *et al.*, 1991).

One sievert of radiation is a large dose and so radiation is commonly measured in millisieverts (mSv) or microsieverts (μSv). The dose equivalent should not exceed 1mSv per year (Hart *et al.*, 1991) The old unit for dose equivalent is the rem (rad equivalent man) where 1Sv = 100 rem.

2.5.2 Single Photon Absorptiometry.

SPA is used for measuring the appendicular girdle. The limb is placed in a "water bed of soft tissue equivalent density " which keeps the length of the beam constant (Schmitz *et al.*, 1990). A photon beam from a radioisotope source is directed at the limb and the amount of attenuation of the beam determines the composition which is measured by a detector (Schmitz *et al.*, 1990). This method is inexpensive, has high accuracy and precision and gives a low dose of radiation. Absorbed dose is 100 μSv, with precision 1 - 3 % and accuracy 2 - 5% (Schmitz *et al.*, 1990; Greenfield, 1992).

2.5.3 Dual Photon Absorptiometry.

DPA uses a system which has a radioactive energy source producing two

photon energy peaks. The differential absorbance by bone produces a contrast between low and high energetic peaks which allows definition of soft tissue and bone areas (Schmitz *et al.*, 1990). There is a 'scan motion' which moves the source and detector across the area of body to be scanned (Greenfield, 1992). This technique can be used to measure spine, hip and total body (Greenfield, 1992), however the precision of this system is approximately the same as changes in bone mass over one year (Rozenberg, Peretz, Praet, Vandromme & Ham, 1993). The absorbed dose is 50 μSv with precision 2 - 4 % and accuracy 4-10% (Schmitz *et al.*, 1990; Greenfield, 1992).

2.5.4 Dual Energy X-ray Absorptiometry.

The DEXA system is similar to DPA in its mode of operation but uses an X-ray tube instead of a radioactive energy source. This method combines high accuracy and precision with low radiation and reduced time (Trevisan, Gandolini, Sibilla, Penotti, Caraceni & Ortolani, 1992). The absorbed dose is 10 - 30 μSv with precision 1 - 2 % and accuracy 3 - 5 % (Schmitz *et al.*, 1990).

2.5.5 Quantitative Computed Tomography.

QCT measures individually separated bone compartments and so can measure high turnover trabecular bone or cortical bone separately or together. It is usually performed on the spine. It is fast, but the radiation

dose is higher than the other techniques. The absorbed dose is 1,000 - 3,000 μSv with precision at 1 - 3% and accuracy 4 - 20% (Greenfield, 1992).

2.5.6 Total Body Scans.

The DEXA and DPA techniques are able to measure total body mineral content and density (Mazess *et al.*, 1990). Soft tissue composition is also able to be determined (Mazess *et al.*, 1990). A total body scan using DEXA can be completed in 10 - 20 minutes compared to 60 - 80 minutes required by DPA (Nuti, Martini, Righi, Frediani & Turchetti, 1991). DEXA is also considered to provide better resolution, precision and lower cost as well as lower radiation (Rozenberg *et al.*, 1993). For these reasons DEXA is considered to be the system of choice when measuring bone mineral density of children (Faulkner, Bailey, Drinkwater, Wilkinson, Houston & McKay, 1993; Kroger *et al.*, 1992; Glastre *et al.*, 1990; Henderson, 1991).

As total body scans gather information from the whole skeleton it is possible to obtain regional values of bone mineral density. This may provide an advantage, particularly in longitudinal studies as bone loss is not uniform throughout the skeleton (LeBlanc *et al.*, 1990). Possible errors for repeat scanning are anatomical positioning and movement during the scan. Results from LeBlanc *et al.* (1990) suggest the trunk, legs, total spine and arms give precision values close to that of local scanning.

2.5.7 Body Composition.

Body composition is traditionally measured by underwater weighing, a technique based on the assumption that the body is divided into two compartments (Johansson *et al.*, 1993). One compartment contains adipose tissue with a density of 0.9 g/cm^3 whilst the other compartment with a density of 1.1 g/cm^3 is composed of muscle and bone and called lean body mass (Johansson *et al.*, 1993). This method therefore considers the density of muscle and bone to be equal. This assumption has not been supported by results obtained from dissections (Ross & Marfell-Jones, 1991) and can also be influenced by fluctuations in amount of body water (Going, Massett, Hall, Bare, Root, Williams & Lohman, 1993). Underwater weighing is also very dependent on subject co-operation. Skinfold caliper measurement is another method used to estimate body fat but relies on major assumptions of subcutaneous fat reflecting fat content of the body and fixed adipose patterning (Ross & Marfell-Jones, 1991). Ross and Marfell-Jones (1991) consider that both underwater weighing and skinfold caliper measurement are not accurate methods for quantifying % body fat and are useful only for comparative purposes.

Body weight as measured by DEXA enjoys a high correlation with weight measured by a high precision scale (r=0.998) (Johansson *et al.*, 1993). Body fat estimation by DEXA however has been found to be significantly lower than

underwater weighing estimation (Johansson *et al.*, 1993) although some researchers have found no differences in women (Van Loan & Mayclin, 1992). The high correlation between body weight as measured by DEXA and the high precision scale indicates DEXA provides an accurate estimation of the soft tissue mass. As Johansson *et al.* (1993) suggests, there may be an error separating the soft mass into fat tissue mass, assuming the underwater weighing technique is correct which as discussed previously is unlikely.

Svendsen, Haarbo, Hassager and Christiansen (1993) determined the accuracy of body composition as measured by DEXA. This group found no significant difference between % fat as measured by DEXA with the real value as measured by chemical fat extraction (r=0.98) and concluded DEXA provided an accurate and precise measurement of body composition (Svendsen *et al.*, 1993). This opinion is upheld by Pritchard, Nowson, Strauss, Carlson, Kaymakci and Wark (1993) who consider DEXA provides a safe, precise, convenient measure of body composition with the added benefit of site specificity.

2.6 Chapter Summary.

Skeletal remodelling will determine the amount and placement of bone tissue throughout the body. Adequate nutrition in the form of high calcium intake, moderate alcohol intake and no smoking will provide a suitable

framework for maximising bone mass.

Genetic determinants and appropriate exercise protocols have been found to exert a profound influence on the development of bone tissue. In particular, weight-bearing exercise of sufficient intensity can provide a stimulus for tissue accumulation. Adolescence has been found to be an important stage in this process. Indeed, prevention of age related osteoporosis may well be moderated by adolescent behaviour although this has yet to be properly determined.

Measurement of bone mineral density , particularly by DEXA is a fast non-invasive technique with little radiation and high precision and accuracy . Total body scans have the added benefit of providing information regarding body composition as well as presenting regional bone mineral density values.

Chapter Three.

Theoretical Framework.

3.1 Study Design.

The design of the study is causal-comparative. Causal-comparative research describes the current status and attempts to determine reasons why there may be differences between specific populations (Gay, 1992). Studies with this research design attempt to identify cause-effect relationships but unlike experimental research, the independent variable, 'the cause' is not created but has already occurred (Gay, 1992).

Studies of this design usually involve two or more groups and one independent variable. Independent variables are variables that cannot be manipulated (Gay, 1992). The groups possess different characteristics or experiences from each other. The groups are then compared on a dependent variable. It is important in a causal-comparative study that the groups are clearly defined and they must be as similiar as possible on all aspects except for the independent variable (Gay, 1992).

3.2 Theoretical Framework.

The theoretical basis for this study is:

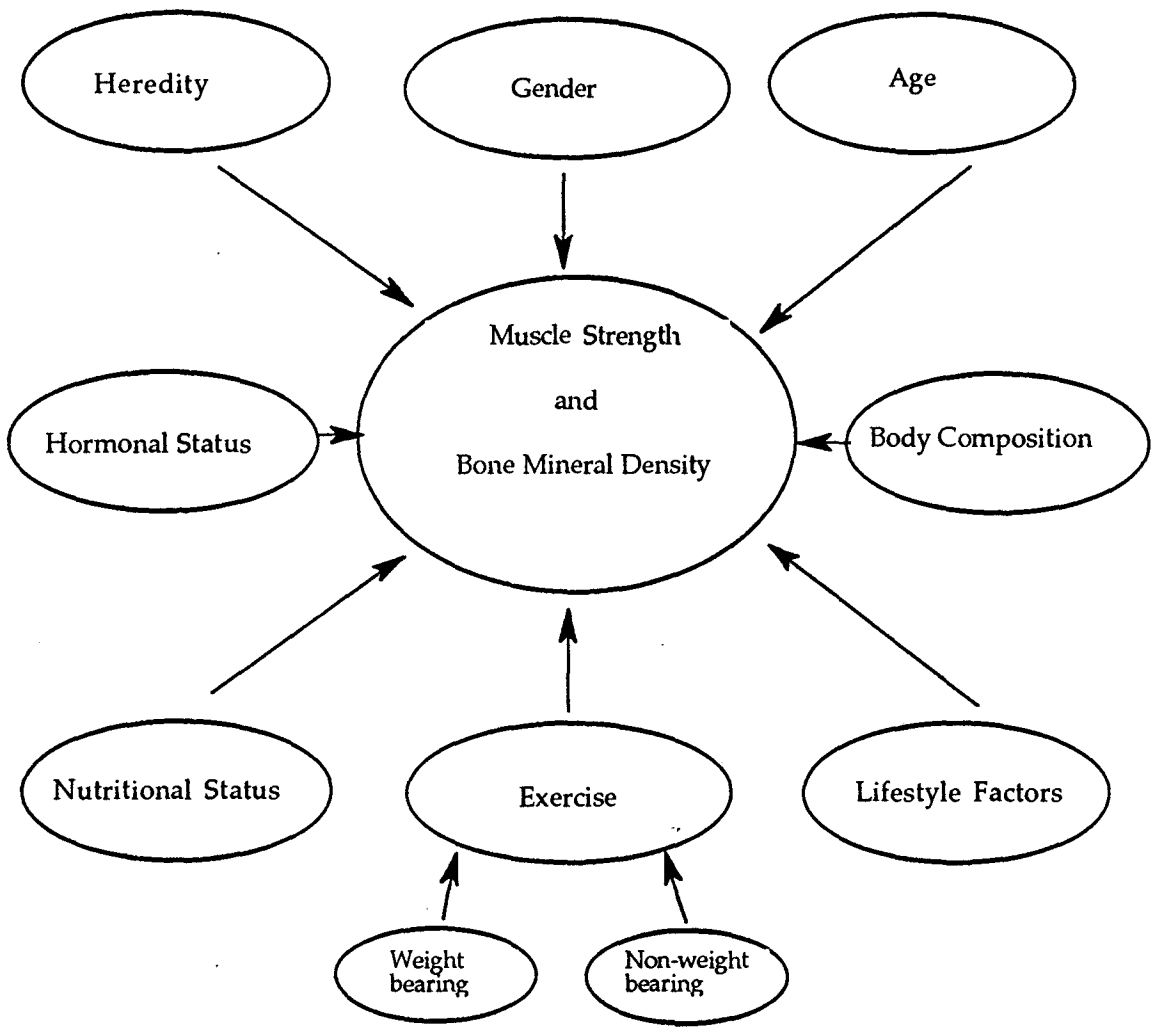

FIGURE 3.1: Theoretical Framework

There are a number of variables having influence on the development of muscle strength and bone mineral density. Weight-bearing exercise is hypothesized to exert a significant effect on musculo-skeletal development.

Chapter Four.

Methodology.

4.1 Subjects.

The subjects for this study were female athletes participating in the 'Australian Masters Games' which were held in Perth, Western Australia in April 1993. The criteria for inclusion in the study were:

a. Peri-menopausal: minimum age of 42 years.

b. Non-smoking.

c. Moderate alcohol intake: approximately 14 units/ week.

d. Long training history in their chosen sport - a minimum of 20 years.

e. Participation in one of the identified activities: swimming, netball, basketball, running and hockey.

f. Competition standard to be a minimum of "A" grade.

g. Particpation in the sport to have commenced during teen (13-14) years.

Permission was sought and gained through the Masters Games organizing committee to gain access to the 'Confederation of Australian Sport' questionnaire. This questionnaire was completed by all potential

competitors in the games and provided information to enable an initial selection of athletes. Questions in this form included the age when participation in the sport first began and the standard reached in that sport. Medical information was also sought as to the participants' state of general health.

From examination of all the questionnaires, a list of potential subjects was compiled. These athletes were approached by letter to determine their interest and willingness to participate in the study. Information regarding their menstrual history and training status was sought by questionnaire.

(See Appendix :
1. letter to Masters Games organizing committee.
2. Australian Confederation of Sport questionnaire.
3. letter to potential subjects.
4. menstrual and training history questionnaire.)

Three groups of 20 were selected. One group was composed of athletes participating in a non-weight-bearing activity, swimming (SWI). The second group was a composite group composed of athletes participating in netball or basketball (NB/BB). The third experimental group consisted of subjects with a backgound in field hockey or running (GEN). The second and third groups were composite as prior contact with sporting associations indicated that it would be difficult to gain 20 subjects from one particular discipline who would meet all requirements. These activities were

considered to be relatively similar. In comparison, the swimming association indicated there was quite a number of Master swimmers who would probably meet the criteria.

The number of subjects drawn from the Masters Games was not sufficient for this project. Approaches were therefore made to appropriate sporting associations to contact any of their members who they considered suitable. Letters with follow-up telephone calls were made and numbers for each group completed.

There were a number of Masters athletes who responded who had very diverse sporting backgrounds. These athletes were not included as an attempt was made to measure only those with a strong background in one particular activity. This proved to be extremely difficult. For example, there were many females who had been swimming for ten years or so but had no background in this activity when young. Also, many of the competitive swimmers had stopped swimming when approximately 16 years due to the intense training load and had only recommenced during their thirties or forties.

A control group of criteria-matched sedentary subjects were recruited from the institution where the study was conducted. Advertisements were placed in the weekly University Gazette and a group of twenty controls was

established.

The protocol for the study was approved by the Ethics Committee of both Edith Cowan University and the Department of Endocrinology and Diabetes at Sir Charles Gairdner Hospital, Queen Elizabeth II Medical Centre. All subjects were told of the nature and risks of the procedures to be used and signed informed consent forms. (Appendix 5) The subjects were also required to sign forms provided by the hospital in order for the bone scanning to occur. (Appendix 6).

4.2 Data Collection.

4.2.1 Questionnaire.

Subjects were asked to complete information regarding current menstruation, smoking and alcohol use. (Appendix 4) They were also asked to estimate historical physical activity in seven age-groups: 6 - 12 years, 13-16 years, 17-20 years, 21-25 years, 26-30 years, 31-40 years and 41-50+ years. Subjects were requested to indicate what activity they had been or were involved in and the number of hours for each age group. Their highest sporting achievment and a rating for their participation in sport throughout their life was also questioned. All subjects in the experimental athletic group rated their involvement as high or greater, while the control

sedentary group rated their involvement as minimal or low. This questionnaire was used to determine suitability of the subject plus it could be ascertained if the subject had participated predominantly in weight-bearing or non-weight-bearing exercise.

4.2.2 Bone Mineral Density.

Bone mineral density was measured using Dual Energy X-Ray Absorptiometry (DEXA: Hologic QDR 2000) in the Department of Endocrinology and Diabetes at Sir Charles Gairdner Hospital, Queen Elizabeth II Medical Complex. Measurement consisted of a whole body scan using an array beam. Subjects removed all metal objects (including underwear: brassiere) and wore a hospital gown. They were positioned in the supine position with hands placed prone on either side of the body with legs held an equal distance apart by a strap. The machine was calibrated daily by scanning of a phantom. The DEXA system has been found to be reliable, with 2% variation between test and re-test. The procedure is non-invasive and gives rapid, clear results (Leboff, El-Hajj Fuleihan, Angell, Chung & Curtis, 1992). The total radiation dose of one DEXA scan is 10-30μSv (Greenfield, 1992) which is 1-3% of the maximum whole body dose considered safe for volunteers by the National Health and Medical Research Council. All bone scans were analysed by the same operator.

4.2.3 Muscle Strength.

Isometric muscle strength of the dominant arm and leg was measured at 90 degrees flexion by electronic cable tensiometer attached to a strength chair (Jones & Round, 1990). The 2 muscle groups to be measured were: arm flexors and leg extensors. Subjects were strapped across the chest and hips with velcro straps to prevent undue body movement. The limb was placed in a cuff and limb position checked to be at 90% flexion. The cuff was placed around the subjects supinated wrist for the arm flexors measurement and the ankle for the leg extensors measurement. Given the limitations of the equipment there was no standardisation of the distance between the measurement of force and the axis of rotation. Subjects were asked to perform three isometric contractions with approximately 10 seconds rest between attempts. The isometric strength was measured using an electronic force transducer (Jones, Rutherford & Parker, 1989) with output fed into a analog to digital converter (Boston Technology PC30G) and displayed on a PC (IBM clone).

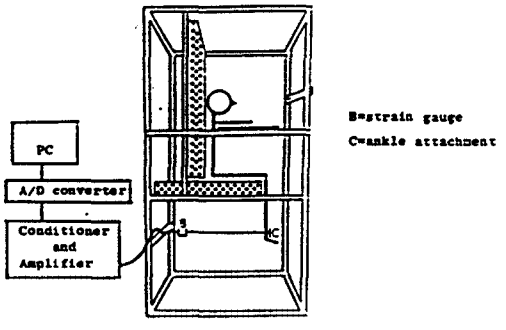

FIGURE 4.1: Apparatus for Measurement of Isometric Strength.

4.2.4 Calcium Intake.

Daily calcium intake was estimated by a food frequency questionnaire which had been adapted from Angus, Sambrook, Pocock and Eisman, (1989). Subjects were asked to estimate amounts of major calcium-containing foods eaten either weekly or in some cases daily. This food frequency questionnaire has been found to be simple to administrate and has a correlation of r=0.79 with a four day food diary which is recognised as being very accurate (Angus *et al.*, 1989). The results from the food frequency questionnaire were analysed on a spreadsheet (MS Works for Macintosh computers) using information from PC Diet software and packaging information. (Appendix 8).

4.2.5 Anthropometric Measures.

Height was measured to the nearest 0.5 cm using a simple stadiometer attached to the hospital wall. Weight was measured by a "chair" beam balance to the nearest half kilogram. Body weight can also be determined by DEXA which is acknowledged an accurate measure (Johansson *et al.*, 1993).

All data were displayed in a table (Appendix 7)

4.3 Data Analysis.

Statistical analysis was performed using the Statview SE/Graphics programme for Macintosh computers. Data were compared between groups using ANOVA, with Scheffe Tests to determine any significant difference. The accepted level of significance was determined to be $p<0.05$. Correlations within groups between variables were performed by Pearson r with an accepted level of significance $p<0.05$.

Chapter Five.

Results.

5.1 Results.

No significant differences were found in the general characteristics of the subjects. Group one consists of females (n=20) with an extensive training history in the high impact sports of netball and/or basketball (NB/BB: 29.4 years). Group three (n=20) is the non-weight-bearing swimming group (SWI: 29.3 years) and Group four (n=20) is a second weight-bearing group with the subjects mainly runners or hockey players (GEN: 29.3 years). Group four also contains three badminton players. Group two (n=20) is composed of sedentary controls (CON). Table 5.1 summarises the general characteristics. All subjects were non-smokers. Data were analysed by a one way ANOVA to determine any significant differences between groups for the variables: age, height, weight, calcium intake and alcohol intake. No significant differences were found.

Group	Age (years)	Height (cm)	Mass (kg)	Calcium (mg/daily)	Alcohol (units/weekly)
NB/BB	45.5 ±3.2	166.3 ±5.9	65.5 ±7.7	806.7 ±391.2	5.5 ±12.1
CON	45.6 ±2.1	165.5 ±8.2	66.7 ±6.6	817.8 ±604.8	1.3 ±2.2
SWI	46.0 ±3.6	165.6 ±8.0	65.7 ±12.6	968.1 ±561.1	3.5 ±2.6
GEN	46.2 ±3.1	163.2 ±6.7	62.5 ±7.5	842.5 ±354.2	6.3 ±5.7

TABLE 5.1: General Characteristics of Study Groups. (Mean ± SD)

The DEXA bone densitometry system is able to measure total body soft tissue as well as total body bone content and density. Lean mass and % fat were analysed by a one-way ANOVA to determine any significant differences between groups. The Scheffe Test, which calculates an F ratio for each mean comparison of interest (Gay, 1992) was then applied to find where the significance lay. The lean mass, as measured by DEXA is the amount of muscle tissue and this was found to be significantly different between the BB/NB (41880.8 g ±4131.4) group and the CON (37618.1 g ±3473.5) group ($F=3.524$: $p< 0.05$) and the SWI (4288.5 g ±4622.3) group and CON group ($F=5.512$: $p< 0.01$). All athletic groups were found to have significantly lower % fat than the CON group. The NB/BB (30.9% ± 6.9) was significantly lower than the CON (39.6% ± 4.4: $F= 6.628$: $p< 0.01$) group. The SWI group (29.0 % ± 7.1 : $F= 9.97$: $p< 0.01$) and the GEN group (31.1 % ± 5.8: $F=6.342$: $p< 0.01$) were also significantly lower than the sedentary group. Isometric quadriceps

strength showed a significant difference by the Scheffe Test between the BB/NB (352 N ±104) group and the CON (263 N ±47: F=4.255: $p < 0.01$). There was no significant difference found in arm strength between any of the groups Means ± SD are displayed in Table 5.2 and F ratios are displayed in Table 5.3.

Group	Lean Mass (gram)	Fat %	Quadriceps (newton)	Biceps (newton)
NB/BB	41880.8 ±4131.4	30.9 ±6.9	352 ±104	207 ±75
CON	37618.1 ±3473.5	39.6 ±4.4	263 ±47	190 ±4
SWI	42885.7 ±4622.3	29.0 ±7.1	305 ±58	200 ±39
GEN	40120.7 ±4246.9	31.1 ±5.8	323 ±81	209 ±41

TABLE 5.2: Lean Mass, % Fat and Isometric Strength of Groups (Mean ± SD).

	CON	SWI	GEN	
NB/BB	6.628 **	0.305	0.003	% Fat
CON		9.97 **	6.342 **	
SWI			0.37	
NB/BB	3.524 *	0.201	0.601	Lean Mass
CON		5.512 **	1.215	
SWI			1.519	
NB/BB	4.255 **	1.185	0.439	Quads Strength
CON		1.068	2.127	
SWI			0.192	
NB/BB	0.335	0.057	0.005	Biceps Strength
CON		0.135	0.447	
SWI			0.101	

TABLE 5.3: F values from ANOVA's for % Fat, Lean Mass, Quadriceps Strength and Biceps Strength in all 4 groups ($p< 0.05$ *, $p<0.01$ **).

The total body scans were analysed by a one-way ANOVA to determine any differences between groups. The BB/NB group had significantly higher bone mineral density than did the CON (BB/NB: 1.150 g/cm^2; CON: 1.019 g/cm^2; $F=8.428$: $p< 0.01$), as did the general athletic group as compared to the controls (GEN: 1.118 g/cm^2; CON: 1.024 g/cm^2; $F=4.77$: $p< 0.01$). The high

impact weigh-bearing group (BB/NB) also displayed a significant difference in total body bone mineral density against the SWI group (BB/NB: 1.150 g/cm^2; SWI: 1.061 g/cm^2; $F=4.016$: $p< 0.05$).

When regional leg (mean) bone mineral density results were analysed the same three results appeared . The NB/BB group had significantly higher leg bone mineral density than the controls (BB/NB: 1.203 g/cm^2; CON: 1.046 g/cm^2; $F=11.047$: $p< 0.01$) and the SWI group (SWI: 1.107 g/cm^2; $F=4.276$): $p< 0.01$). The GEN group also had significantly greater leg bone mineral density than the controls (GEN: 1.179 g/cm^2; $F=7.884$: $p< 0.01$).

Bone mineral density scores obtained from regional arm results (mean) showed group one , the NB/BB group to have significantly higher arm bone mineral density than the control group (BB/NB: 0.733 g/cm^2; CON: 0.666 g/cm^2; $F=5.762$: $p< 0.01$). Bone mineral density results (mean $\pm$ SD) are summarised in Table 5.4 with F ratios displayed in Table 5.5.

Groups	Total Body g/cm^2	Regional Leg g/cm^2	RegionalArm g/cm^2
NB/BB	1.150	1.203	0.733
	±0.085	±0.088	±0.051
CON	1.024	1.046	0.666
	±0.070	±0.077	±0.048
SWI	1.061	1.107	0.711
	±0.080	±0.087	±0.051
GEN	1.118	1.179	0.707
	±0.095	±0.090	±0.054

TABLE 5.4: Total Body and mean Regional Bone Mineral Density of Study Groups (Mean ± SD).

	CON	SWI	GEN	
NB /BB	8.428 **	4.016 *	0.517	Total Body B.M.D.
CON		0.873	4.77 **	
SWI			1.629	
NB /BB	11.047 **	4.276 **	0.266	Mean Leg B.M.D.
CON		1.68	7.884 **	
SWI			2.389	
NB /BB	5.762 **	0.662	0.879	Mean Arm B.M.D.
CON		2.612	2.14	
SWI			0.018	

TABLE 5.5: F values from ANOVA's for Total Body and Regional Bone Mineral Density for all 4 groups ($p< 0.05$ *, $p< 0.01$ **).

Correlations were computed by Pearson r to determine any relationship between variables.

Total bone mineral density was correlated with calcium intake in all four groups. No relationship was noted. (BB/NB: r = -0.181; CON: r = 0.24; SWI: r = -0.351; GEN: r = 0.222). Lean mass was correlated with total body bone mineral density. (BB/NB: r = 0.478*; CON: r = 0.323; SWI: r = 0.490*; GEN: r = 0.315). The correlations between the BB/NB group and the SWI groups were statistically significant at $p<0.05$ * (correlation co-efficient = 0.4438). Finally, % fat was correlated with total body bone mineral density. (BB/NB: r=-0.061; CON: r = -0.294; SWI: r = 0.086; GEN: r = -0.066). No relationship was found.

Quadriceps strength was correlated with mean leg bone mineral density (BB/NB: r = 0.575**; CON: r = 0.185; SWI: r = 0.672**; GEN: r = 0.504*). The correlations in NB/BB and SWI were significant at $p<0.01$** and the GEN at $p<0.05$*. Biceps strength was correlated with mean arm bone mineral density (BB/NB: r = 0.189; CON: r = -0.084; SWI: r = 0.443*; GEN: r = 0.098). The correlation between biceps strength and arm bone mineral density was significant at $p<0.05$* for the SWI group. Results are summarised in Table 5.6.

B.M.D. sites	Calcium intake	Lean Mass	% Tot Fat	Quadriceps strength	Biceps strength
Total					
NB/BB	r=-0.181	r=0.478*	r=-0.061		
CON	r=0.240	r=0.323	r=-0.294		
SWI	r=-0.351	r=0.490*	r=-0.086		
GEN	r=0.222	r=0.315	r=-0.066		
Leg					
NB/BB				r=0.575**	
CON				r=0.185	
SWI				r=0.672**	
GEN				r=0.504*	
Arm					
NB/BB					r=0.189
CON					r=-0.084
SWI					r=0.443*
GEN					r=0.098

TABLE 5.6: Results of Pearson correlations between Bone Mineral Density sites and Calcium Intake, Lean Mass, % Fat, Quadriceps Strength and Biceps Strength ($p<0.05^*$ and $p<0.01^{**}$).

The correlations were also graphed and are represented on Figures 5.1(a) - 5.5(d).

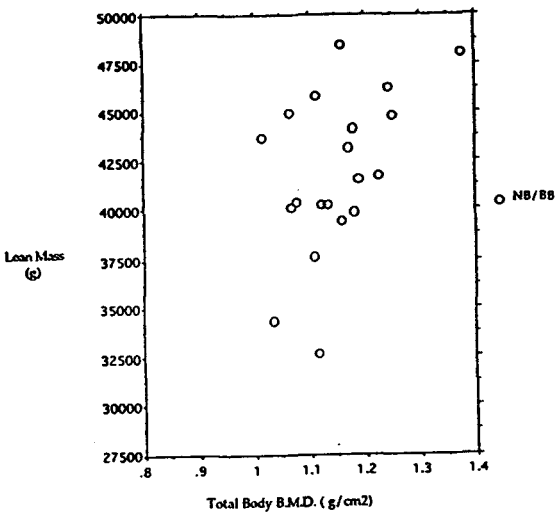

FIGURE 5.1 (a): Scattergram of Lean Mass vs Total Body B.M.D. in the NB / BB group.

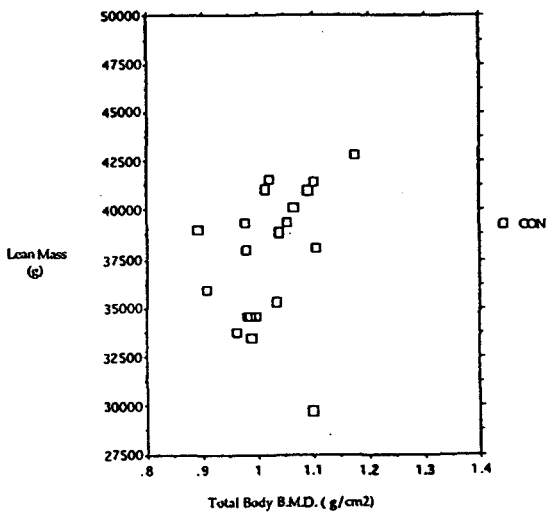

FIGURE 5.1 (b): Scattergram of Lean Mass vs Total Body B.M.D. in the CON group.

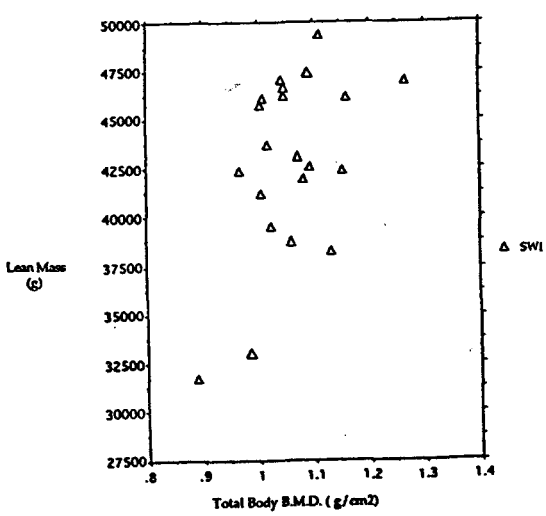

FIGURE 5.1 (c): Scattergram of Lean Mass vs Total Body B.M.D. in the SWI group.

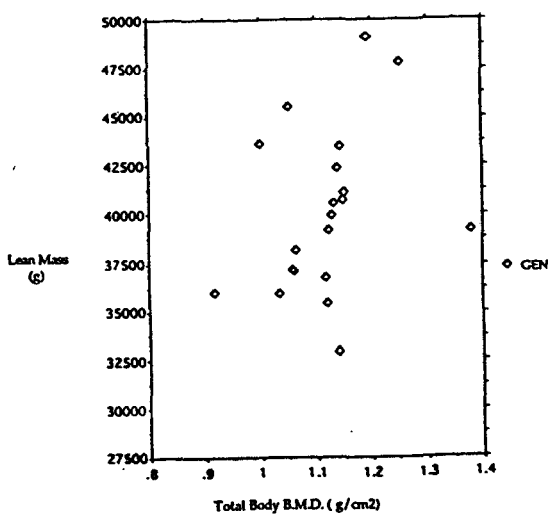

FIGURE 5.1 (d): Scattergram of Lean Mass vs Total Body B.M.D. in the GEN group.

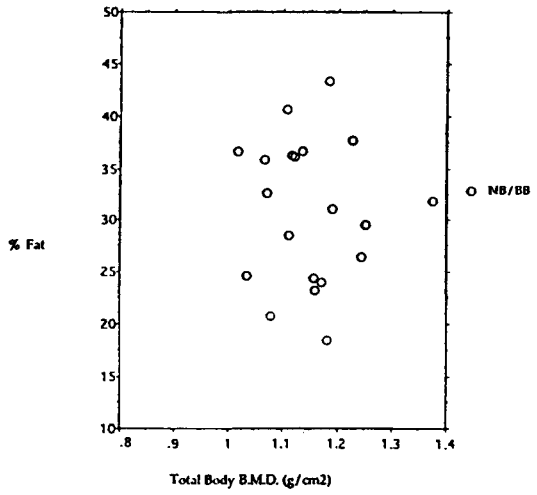

FIGURE 5.2 (a): Scattergram of % Fat vs Total Body B.M.D. in the NB /BB group.

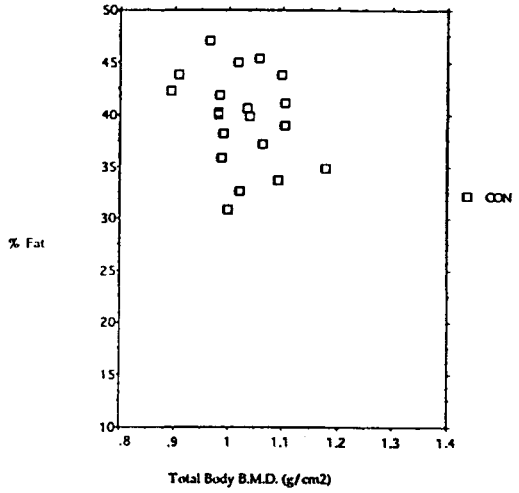

FIGURE 5.2 (b): Scattergram of % Fat vs Total Body B.M.D. in the CON group.

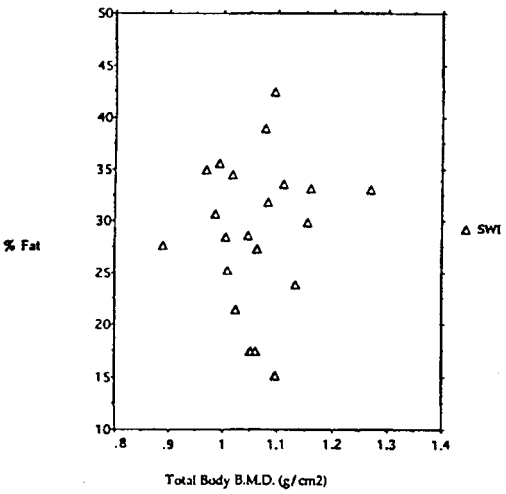

FIGURE 5.2 (c): Scattergram of % Fat vs Total Body B.M.D. in the SWI group.

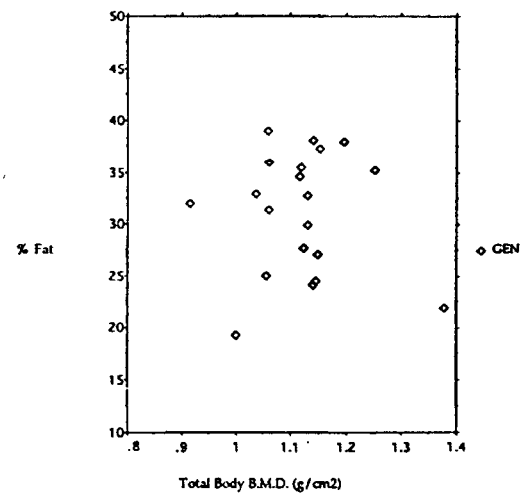

FIGURE 5.2 (d): Scattergram of % Fat vs Total Body B.M.D. in the GEN group.

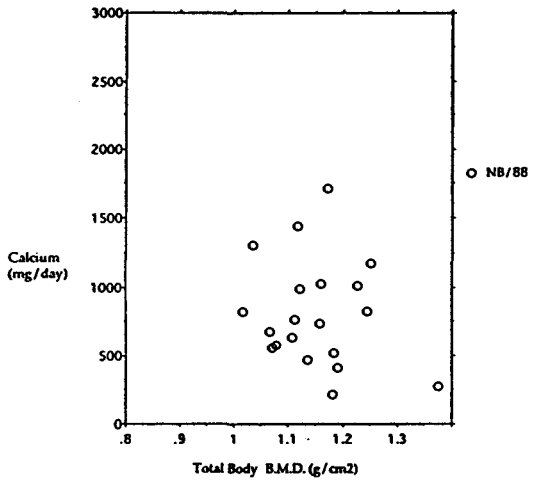

FIGURE 5.3 (a): Scattergram of Calcium Intake vs Total Body B.M.D. in the NB / BB group.

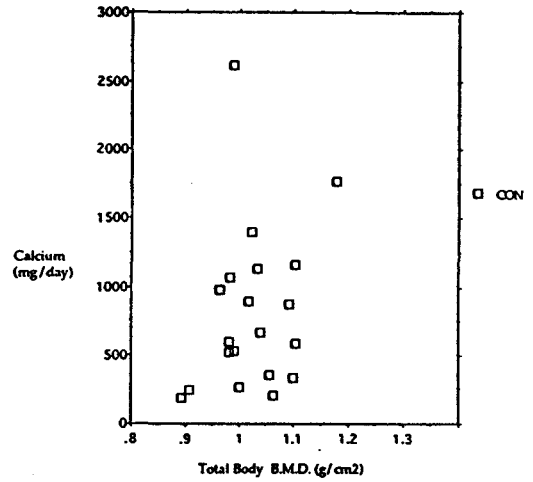

FIGURE 5.3 (b): Scattergram of Calcium Intake vs Total Body B.M.D. in the CON group.

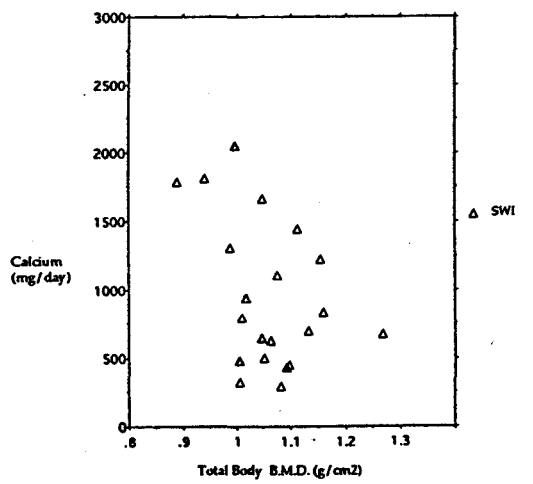

FIGURE 5.3 (c): Scattergram of Calcium Intake vs Total Body B.M.D. in the SWI group.

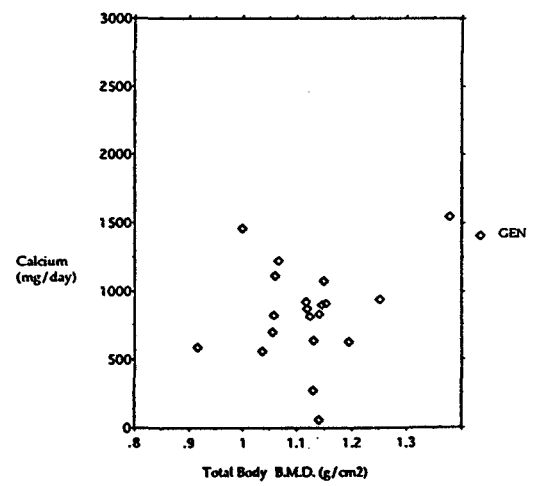

FIGURE 5.3 (d): Scattergram of Calcium Intake vs Total Body B.M.D. in the GEN group.

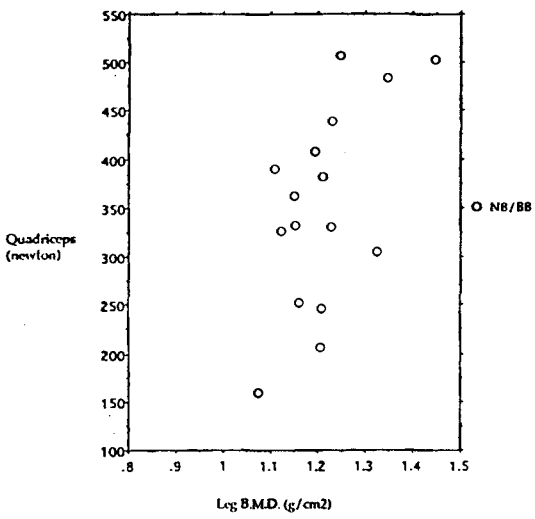

FIGURE 5.4 (a): Scattergram of Leg B.M.D. vs Quadriceps Strength in the NB /BB group.

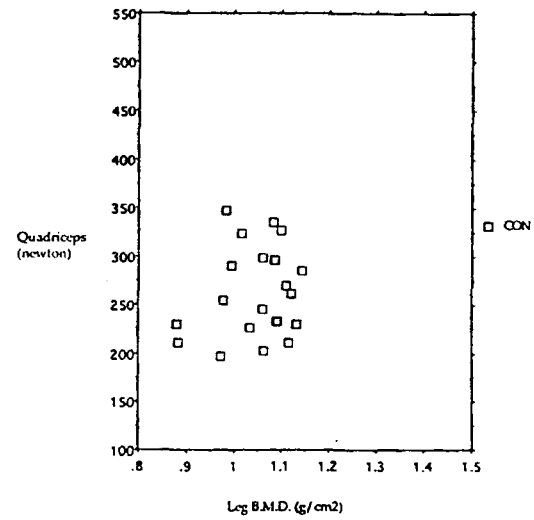

FIGURE 5.4 (b): Scattergram of Leg B.M.D. vs Quadriceps Strength in the CON group.

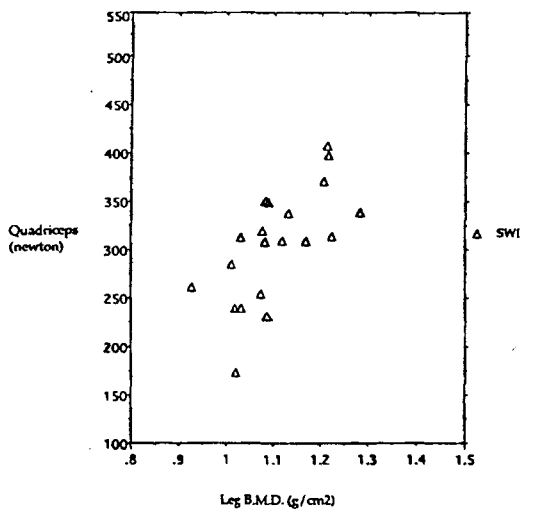

FIGURE 5.4 (c): Scattergram of Leg B.M.D. vs Quadriceps Strength in the SWI group.

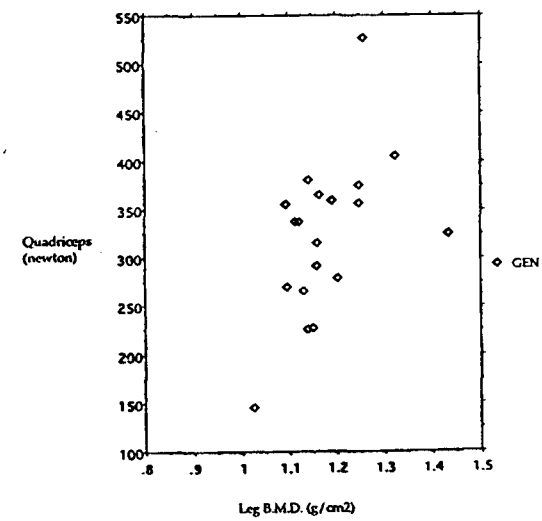

FIGURE 5.4 (d): Scattergram of Leg B.M.D. vs Quadriceps Strength in the GEN group.

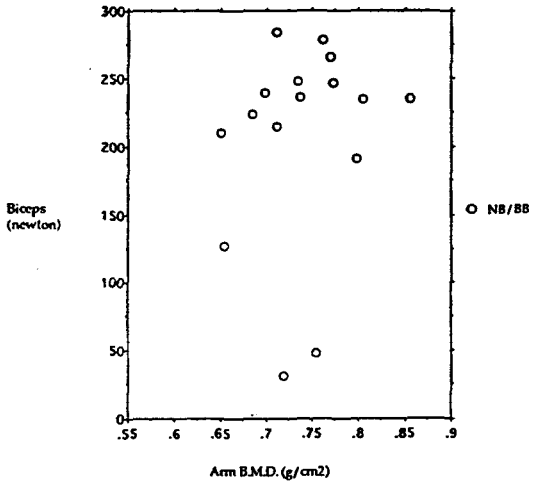

FIGURE 5.5 (a): Scattergram of Arm B.M.D. vs Biceps Strength. in the NB / BB group.

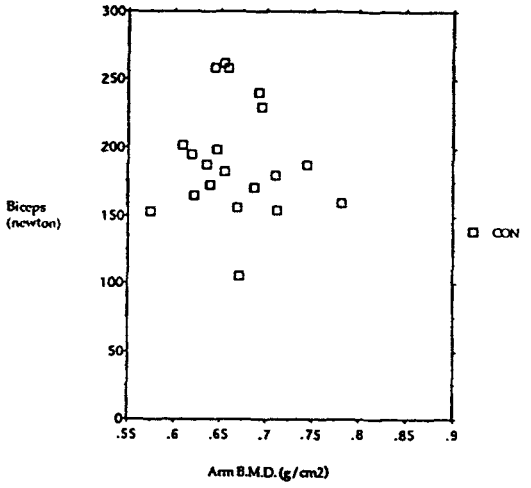

FIGURE 5.5 (b): Scattergram of Arm B.M.D. vs Biceps Strength. in the CON group.

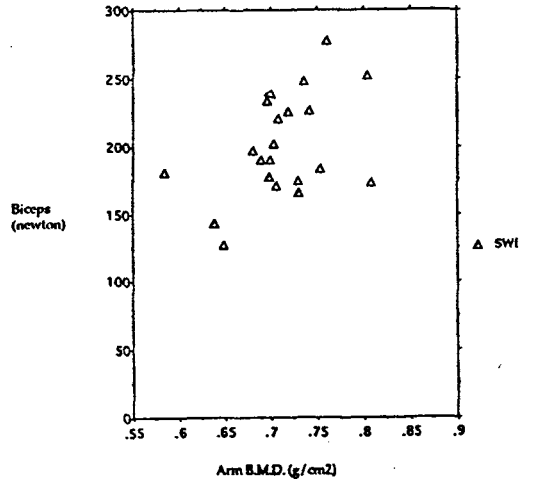

FIGURE 5.5 (c): Scattergram of Arm B.M.D. vs Biceps Strength. in the SWI group.

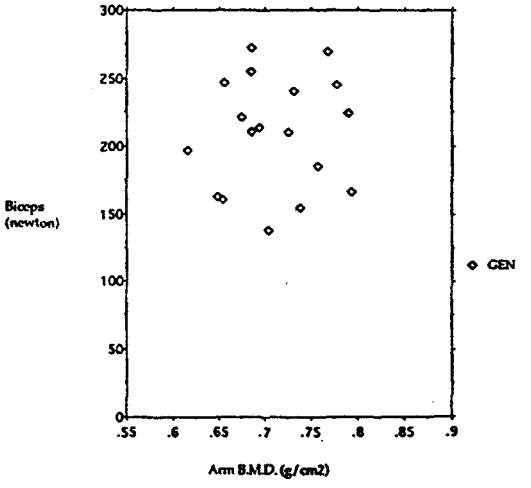

FIGURE 5.5 (d): Scattergram of Arm B.M.D. vs Biceps Strength. in the GEN group.

Historical activity in hours / week as estimated by the subjects was then correlated against adult total body bone density results. Three major age groups were selected: 13-20 years (r=0.164), 20-30 years (r=0.226) and 30-45 years (r=0.222). The correlations for the 20-30 years and 30-45 years were significant at $p < 0.05$ (correlation co-efficient = 0.2172). These results are summarised in Table 5.7 .

Total Body B.M.D.	13-20 years	20-30 years	30-45+ years
All subjects (n=80)	r=0.164	r=0.226*	r=0.222*
NB/BB	r=0.122	r=-0.343	r=0.174
CON	r=0.25	r=-0.119	r=-0.167
SWI	r=-0.112	r=0.075	r=-0.064
GEN	r=0.128	r=0.236	r=0.034

TABLE 5.7: Estimated Historical Activity in hours/week in three age brackets correlated against Total Body Bone Mineral Density ($p < 0.05$ *).

Chapter Six.

Discussion.

6.1 Major Findings.

6.1.1 Introduction.

The overall aim of this study was to investigate the effect of a lifetime of weight-bearing activity on bone mineral density in perimenopausal women. Variables such as height, weight, dietary calcium , age, menstrual status, smoking and alcohol intake were controlled for, and no significant differences were found between the athletic groups (NB/BB, SWI & GEN) and sedentary (CON) group for any of these factors. Isometric strength of the dominant limb leg extensors (quadriceps) and arm flexors (biceps) was also measured.

In this study, athletic groups were selected on the basis of their long term training histories in weight-bearing or non-weight-bearing activities and the control group was selected on the basis of their lack of training. Placement into groups was based on the subjects recall of past training and it is possible that the estimation of training history may not have been accurate. There was also no consideration of intensity of training, although this was partially addressed by only selecting subjects who had competed at a minimum of "A

Grade" standard. A number of the subjects had been state or national representatives and this was considered to represent an intense level of training. Menstrual status was not confirmed and historical menstrual patterns were not considered. It also proved difficult to find subjects who had participated exclusively in one type of exercise therefore two of the athletic groups: NB/BB and GEN were composite in nature. Many of the subjects in the NB/BB group had participated in both these sports which are considered to be similar. Hockey and running also share features and so subjects involved in these sports formed the GEN group.

6.1.2 Nature of Activity.

One of the major findings of this study was that long-term involvement in a weight-bearing activity such as netball resulted in greater total body and leg bone mineral density than long term participation in the non-weight-bearing activity of swimming. Both weight-bearing groups (NB/BB & GEN) had significantly greater total body and leg bone mineral density than the controls (CON). Previous findings (Stillman *et al.*, 1986; Nilsson & Westlin, 1971; Block, Genant & Black, 1986) confirm these results. Exercise definitely exerts a positive effect on bone tissue although athletes may enjoy a genetic disposition to physical activity. Due to the cross-sectional nature of this study, establishing a relationship between the independent variable, training, and the results is difficult. For example, heredity may be

responsible for the selection of athletic females with a genetic blueprint determining muscle and bone development. The athletic females may have achieved higher bone mineral density regardless of their training history. Evidence however suggests, that even though heredity exerts a major influence, lifestyle factors are important in maximizing bone and muscle development (Kelly *et al.*, 1990; Krall & Dawson-Hughes, 1993).

An interesting result in this study is that a lifetime of swimming (SWI: [tot body B.M.D.] 1.061 g/cm^2), at a competitive level has produced bone mineral density values significantly lower than the NB/BB group (NB/BB: 1.150 g/cm^2) and only slightly higher than the sedentary subjects (CON: 1.024 g/cm^2). Swimming is generally a repetitive activity and is associated with low gravitational forces and resistance. Upper body strength is a major determinant of swimming success (Costill, Maglischo & Richardson, 1992; r=0.93), particularly in males, and the only measure which the SWI group (0.711 g/cm^2) recorded a slightly higher value than the GEN group (0.707 g/cm^2) was arm bone mineral density, although the bicep strength scores showed no significant difference between any of the groups.

The influence of ground reaction forces may be strong. There was a definite trend with the higher impact group, NB/BB having greater total body (1.15 g/cm^2), arm (0.733 g/cm^2) and leg (1.203 g/cm^2) bone mineral density than

the lower impact group (GEN: [tot] 1.118 g/cm^2; [arm] 0.707 g/cm^2; [leg] 1.179 g/cm^2) although these results were not statistically significant. The GEN group did not record a statistical difference between the SWI ([tot body B.M.D.] 1.061 g/cm^2; [arm] 0.711 g/cm^2; [leg] 1.107 g/cm^2) group.

Lanyon (1992) considers evidence from animal work to suggest repetitive, lower peak loads do not exert as great an osteogenic response as high strain loads, and that running will not be as effective as shorter episodes of more intense weight-bearing activity. Running generates ground reaction forces 2 - 3 times body weight (Cavanagh & LaFortune, 1980) whilst in netball, ground reaction forces are in the order of 3.9 - 4.6 times body weight (Steele & Milburn, 1987). Netball is also a game characterised by short intense passages of play while running is more repetitve. Three of the individuals in the GEN group were badminton players. Initially it was anticipated there would be a greater number of badminton players represented in the study. Badminton is also a game with quick changes of direction, leaps when playing a smash and brief, concentrated periods of play. Unfortunately, to my knowledge there are no studies detailing ground reaction forces experienced during badminton. Two of the badminton subjects recorded very high bone mineral density (Subject 1: [tot] 1.377 g/cm^2; [arm] 0.795 g/cm^2; [leg] 1.434 g/cm^2: Subject 2: [tot] 1.196 g/cm^2; [arm] 0.773 g/cm^2; [leg] 1.259 g/cm^2). The results from the bone mineral density measures between

the groups agree with Lanyon's (1992) theory. The activities aligned with high impact are allied with higher bone mineral density values. The repetitive, lower strain activities such as running, hockey and swimming are associated with lower scores, although all athletic groups had higher bone mineral density than the sedentaries but there was no statistical significance between the SWI and CON. This result is similar to Orwoll *et al.* (1989) who found no significant difference in bone mineral density of the radius and vertebrae (T12 - L1) between female swimmers and non-exercisers. As suggested by Orwoll *et al.* (1989) possibly the muscular forces generated by female swimmers are not sufficient to produce a greater osteogenic response than that generated by normal day to day activities. Certainly, the SWI group did not record greater arm and leg strength than the CON group which would seem to indicate support for such a statement.

Buchanan *et al.* (1988) in their study of athletic and sedentary women aged between 18 - 22 years however found no significant differences in trabecular bone density of the lumbar spine between exercisers and non-exercisers. The athletes had been committed to sports during their teen years and had participated in field hockey, basketball or athletics. In contrast however, Grimston, Willows and Hanley (1993) in a study of children involved in high impact activities (>3 times body weight) and non-weight-bearing exercise (swimming) found the high impact group had significantly greater femoral neck bone density. Bone mineral density of the lumbar spine

showed no significant differences between groups.

The nature of the activity may be important in maximizing bone density. High impact activities may be associated with higher bone density whilst low impact or non-weight-bearing activities may not offer enough stress to the skeleton to influence bone remodelling.

6.1.3 Body Fat and Bone Mineral Density.

The results from the DEXA measurements of body composition are interesting. All athletic groups recorded significantly lower percentage fat (NB/BB: 31%; SWI: 29%; GEN: 31%) than the sedentary group (CON: 39.6%) although weight was very similar between groups (NB/BB: 65.5 kg; CON: 66.7 kg; SWI: 65.7 kg; GEN: 62.5 kg). Lean mass was significantly greater in the NB/BB group (41880.8 g) and SWI (42885.7 g) groups than the CON (37618.1 g). The GEN score (40120.7 g) although greater than the CON was not statistically significant.

Traditionally, higher body weights are associated with higher bone density (Dawson-Hughes *et al.*, 1993) due to hormonal benefits of estrogen production in adipose tissue (Frisch, 1990) and biomechanical loading on the skeleton (Nelson *et al.*, 1993). The four groups all had similar body weight but the athletic groups (NB/BB, SWI & GEN) had nearly 10% less fat than

the CON group. The total and leg bone mineral density of the NB/BB and GEN were significantly greater than the non-exercisers, and although not statistically significant the SWI group also registered a higher score. When % fat was correlated with total body bone mineral density no significant correlations were found (NB/BB, r=0.061; CON, r=0.294; SWI, r=0.086; GEN, r=0.066). Exercise, in particular weight-bearing activity may exert a greater influence on bone mineral density than the amount of adipose tissue.

Liel *et al.* (1988) in a study of premenopausal women found that obese women had greater bone mineral density in the lumbar spine, femoral neck and trochanter than non-obese women. In Liel *et al.* (1988) study the exercise habits of the participants were not considered and obesity was determined solely by body weight. This may not accurately reflect body fat. Bevier *et al.* (1989) also found that weight correlated with spine density ($r=0.42$, $p<0.01$). Myburgh, Bachrach, Lewis, Kent and Marcus (1993) however found no correlation between bone mineral density and % fat in athletes. McCulloch, Bailey and Rasmussen (1992) report no relationship between body weight and trabecular bone density of the os calcis in pre-menopausal women.

It would appear the athletic subjects in our study did not have 'low' body fat and still enjoyed the protective effects of estrogen. The importance of body fat as a contributor to bone mineral density may rise after menopause or be

significant when there is low body fat (< 17%: Frisch, 1990) due to the conversion of androgens to estrogens in the adipose tissue.

6.1.4 Lean Mass and Bone Mineral Density.

DEXA is also able to measure lean mass (muscle tissue only) and the NB/BB (41880.8 g) and SWI (42885.7 g) groups were found to have a greater lean mass than the CON (37618.1 g). The GEN (40120.7 g) group followed this trend although the result was not statistically significant. This is possibly a predictable result as exercise is associated with hypertrophy of muscle tissue (Jones & Round, 1990).

When lean mass was correlated with total body bone mineral density, the NB/BB group ($r=0.478$; $p<0.05$) and SWI group ($r=0.490$; $p<0.05$) recorded significant results while the GEN ($r=0.315$) and CON ($r=0.323$) groups scores, whilst not significant, indicated a trend that the greater the lean mass, the higher the bone mineral density scores.

Bone remodelling and hence accrual of bone tissue is influenced by mechanical stress and muscular contractions are able to provide skeletal stress. In the frequently cited study of Doyle, Brown and Lachance (1970); a correlation ($r=0.72$) was found between the bone mineral content of the third lumbar vertebrae and the weight of the left psoas muscle in 46 cadavers.

Heinrich *et al.* (1990) found that fat-free body weight was significantly correlated with bone mineral content at the proximal femur, greater trochanter and vertebrae (L2-4) in pre-menopausal athletes. A larger muscle mass is capable of exerting greater force on the skeleton.

The results from the body composition data indicate the importance of regular exercise over a period of years for both bone and general health. All athletic groups displayed a lower percentage of body fat which is associated with a lower risk of cardiovascular disease. Similarly, greater muscularity lessens the chance of falls.

6.1.5 Muscle Strength and Bone Mineral Density.

When quadriceps muscle strength was correlated with leg bone mineral density the three athletic groups recorded significant results (NB/BB: $r= 0.575$; $p< 0.01$, SWI: $r=0.672$; $p< 0.01$, GEN: $r=0.504$; $p< 0.05$). The SWI group also recorded a significant correlation for biceps strength and arm bone mineral density (SWI: $r=0.443$; $p<0.05$).

The effect of muscular contractions has been assumed to be site-specific (Snow-Harter & Marcus, 1991) and these data support such claims. All of the sports represented in this study involve a high degree of leg useage, although only the NB/BB group were significantly higher in quadriceps

strength than the CON. There is however a definite tendency with the high impact sport of netball producing the highest quadriceps strength (NB/BB: 352N) followed by running/hockey (GEN: 323N) and then the zero impact swimming group (SWI: 305N). The non-exercisers recorded the lowest score for quadriceps strength (CON: 263N). The muscular contractions generated by the activity together with the stress from impact may possibly contribute to bone mineral density. This concept is further supported by the arm results. The only activity requiring extensive use of the arms was swimming and this group registered a significant correlation of biceps strength with arm bone mineral density.

Two of the NB/BB subjects however recorded extremely low scores for biceps strength (31N and 48N). The reason for this is unknown. The subjects did not report any fatigue or medical problem and other scores, eg. lean mass, for both subjects were within the groups range (Lean Mass: 40260.7g and 39460.6g - NB/BB: Mean $\pm$ SD 41880.8g $\pm$ 4131.4). It is possible that the lack of standardisation of the site for the measurement of strength and the limitations of the apparatus may have contributed. Even though there was a definite attempt to ensure that all subjects held limbs at 90% flexion, the hand supinated and the cuff placed on the wrist, the cable attaching the tensiometer could not be significantly lengthened or shortened. Differences in limb length could therefore influence the results with some subjects unable to attain 90 degrees flexion. These 2 subjects may also have

found it difficult to fully activate the muscle or understand how to perform an isometric cotraction.

It was decided to measure isometric strength rather than isokinetic (moving) strength for two main reasons. As a number of the subjects were interstate visitors only here for the duration of the Masters' Games, to encourage participation only one measurment session was scheduled. Use of an isokinetic dynamometer would have entailed two appointments at two locations a significant distance apart. It was anticipated that many of the subjects would not have participated if there was a greater call on their time. Secondly, it was thought that a lifetime of exercise would result in improved overall muscular strength and ability to activate muscle (Hopp, 1993) as opposed to a sedentary existance. Measuring isometric strength of dominant arm and leg muscles does not however measure muscle activity associated with different sports. The muscle useage patterns of a hockey player would be considerably different from those of a swimmer.

Halle *et al.* (1990) reported of a positive relationship between trunk muscle strength and bone mineral density of the lumbar spine in post-menopausal women. Snow-Harter *et al.* (1990) also found site-specific relationships: grip strength was correlated to mid-radius bone mineral density (r=0.47) and hip adductors were positively associated with hip density (r=0.42). The correlations between muscular strength and bone mineral density in the

literature whilst significant, are not strong. As seen in the example of swimming, an aerobic activity requiring considerable strength there appears to be little skeletal benefit. When the added stress of gravitational impact is added a greater osteogenic response appears to occur.

6.1.6 Calcium Intake.

Present calcium intake showed no statistical difference between the four groups (NB/BB: 806 mg/day, CON: 817 mg/day, SWI: 968 mg/day, GEN: 842 mg/day). The food frequency questionnaire for the estimation of dietary calcium however gives no indication of historical calcium intake. It may well be that the athletic groups had a greater calcium intake than the sedentary group during adolescence. This was not determined.

There were no significant correlations found between calcium intake and bone mineral density. This result confirms previous findings (Angus *et al.*, 1988; Riggs *et al.*, 1987; Martin & Houston, 1987) that there is no relationship between adult calcium intake and bone mineral density. The importance of dietary calcium during childhood, particularly adolescence however is not clear. The results from Sandler *et al.* (1985) who measured historical childhood milk consumption and found a significant correlation with adult bone mineral density suggests a positive link. Matkovic *et al.* (1979) study of two areas in Yugoslavia with different calcium intake resulting in greater

rates of hip fracture in the aged in the low calcium intake region also support the importance of childhood dietary calcium. The effect of childhood diet on bone mineral density cannot be determined by this study. Anecdotal evidence however disclosed that the individual subject with the second highest total body bone mineral density (1.375 g/cm^2) had a very low estimated calcium intake (276 mg/day) and stated they had rarely eaten dairy products or calcium containing foods as a child. Obviously, this question requires further investigation.

6.1.7 Historical Activity.

Due to the importance of the teen years in maximizing bone mineral density it was considered that there may be a link between hours of activity as a teenager and adult bone mineral density. Participants were therefore asked to estimate historical activity in terms of type of exercise and hours per week. Responses were categorized into three age brackets: 13-20 years, 20-30 years and 30-45$^+$ years and these results were then correlated with adult total body bone mineral density scores. No statistical significance was found, although when all subjects were grouped together, activity at age 20-30 years ($r=0.226$) and 30-45$^+$ years ($r=0.222$) were significantly correlated with adult bone mineral density, but the correlations are weak. This result suggests that regular activity may be associated with maintenance of bone mineral density.

Recalling events of approximately 30 years ago is likely to be of limited accuracy and many subjects stated they had found it difficult. Even so, with the importance of the teenage years for the development of bone tissue it is reasonable to consider there would be an association. This relationship was not evident from these data. A second explanation may be that volume, or hours per week may have little relationship to the attainment of peak bone mass but rather that intensity may be the key. The questionnaire gives no indication of strength of effort: playing netball for an hour during a school physical education class would provide much lower intensity exercise than training for an hour with an elite junior team. The nature of the activity in terms of impact may provide greater stress to the skeleton rather than longer hours of repetitive or lower impact exercise.

6.2 Summary of Study.

In summary therefore this study has found that a lifetime of weight-bearing exercise is associated with greater total and leg bone mineral density than involvement in a non-weight-bearing activity or a sedentary lifestyle. Research hypothesis 2 has been supported. The NB/BB group recorded a significant difference in quadriceps strength from the non-exercisers, but although a distinct pattern was displayed no further statistical differences were found regarding strength, although it is possible that the equipment limitations contributed to the lack of findings. Research hypothesis 1

therefore is partially supported in terms of significant differences in bone mineral density between experimental and control groups being shown. Research hypothesis 3 has partially been supported as well, as body fat and calcium intake have been found to have no relationship with bone mineral density. Lean mass and bone mineral density however have demonstrated a significant relationship. This would indicate body composition, in particular lean mass or muscularity is an important factor in the development of bone mineral density. Results have shown that all athletic participants had a lower percentage of body fat and greater lean mass than the non-exercisers which would encourage a regular exercise programme to be maintained. Lastly, there is a suggestion that the characteristics of the activity may be influential in establishing and possibly maintaining high bone mineral density.

6.3 Recommendations for Further Research.

Many questions can be highlighted from this study but need to be addressed during the developmental years. It is firmly established that physical activity has a positive effect on bone tissue but the importance of calcium in the childhood diet has yet to be confirmed. The debate between intensity and type of activity or volume of training is another area of research. The importance of impact and skeletal stress requires further study, particularly considering the potential for joint injury. A high impact sport may

potentiate bone mineral density but may seriously damage skeletal joints over a number of years. Establishing suitable exercise protocols that serve to maximize bone mineral density that could be employed in schools would be of benefit to females and may provide a model for life-long exercise participation. Heredity is also an issue of consequence. Athletic individuals may have a greater potential due to their genotype to develop high bone mineral density, with factors such as diet and type of activity being of lesser importance. The new discoveries involving genetic research may offer answers to these questions.

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APPENDIX 1.

Dear Ms Zanfondern,

The Sports Science Dept of Edith Cowan University in collaboration with the Endocrinology Department of Sir Charles Gairdner Hospital, Queen Elizabeth II Medical Centre are currently researching the effects of exercise on muscle strength and bone density. The next step in our research is to study the effects of extended training histories, to discover whether physical activity prevents the loss of muscle strength and bone mineral loss that usually occurs with aging. Our specific area of interest is with pre-menopausal females and to this end we require female volunteers, approximately 45 years with long training histories. The 1993 Masters Games presents a good opportunity to assess such a rare group of people. The results of our proposed measurements would be freely available to participants and are personally beneficial in that they may indicate any undue muscle wasting and bone mineral loss. The value to society is also important if lifelong practices of physical exercise are shown to delay the effects of aging on muscle and bone.

The tests themselves are simple, painless and non-invasive. Muscle strength is assessed by Dual Energy X-ray Absorptiometry (DEXA). The total radiation dose of one DEXA scan is about 1/100th of that used in an ordinary plane X-ray and is considered negligible by the National Health & Medical Research Council. We estimate the total testing time plus transport to be approximately 1.5 - 2 hours.

The 4th Australian Masters Games in 1993 represents an excellent opportunity to carry out this valuable research and we would greatly appreciate any co-operation that you may care to give. Ideally we would like

1. Your approval and support of the above research project.
2. Access to you standard questionnaire, to assess suitability of the athletes.
3. Your permission to approach suitable Masters competitors.

Thank you for taking time to read this proposal and I look forward to any comments you may make in your reply.

Yours sincerely,

Dr Colin JAMES.

'ENDIX 2.

Confederation of Australian SPORT Incorporated

FOURTH AUSTRALIAN MASTERS GAMES

The Confederation of Australian Sport, the licensing agent for the Australian Masters Games, is conducting this research to establish a profile of Masters sport participants to facilitate planning of future Masters sport events to meet the needs of mature aged sports people.

The information supplied in this profile will be treated with the strictest confidence.

The medical information supplied in the medical section will be used to assist in the provision of medical support at the Fourth Australian Masters Games and then will be used for statistical purposes.

'* Please return this Questionnaire with your Registration/Entry form **

YOUR SPORTS PROFILE

☐ Female ☐ Date of Birth _____

rt are you entering in? _____

have you been
g in this sport? _____

were you when you
iis sport? _____

e highest
mpetition
achieved in
? Senior International ☐
Junior International ☐
Senior Interstate ☐
Junior Interstate ☐
Other Senior Rep* ☐
Other Junior Rep* ☐
Grade ☐
Under Age ☐

pecify
_____

e your expecta-
n you took up this
port? (Tick as
te)
Social Activity ☐
Fitness ☐
Local Competition ☐
Elite Competition ☐
Skills Development ☐
Travel ☐
Other* ☐

pecify
_____

se expectations met? YES ☐ NO ☐

Do you play this sport regularly? YES ☐ NO ☐

If Yes, how often? _____

What sport/s did you play before competing in your present sport?

_____

_____

What was the highest level of competition you have achieved in this/these sports?

*Please specify

_____

Senior International ☐
Junior International ☐
Senior Interstate ☐
Junior Interstate ☐
Other Senior Rep* ☐
Other Junior Rep* ☐
Grade ☐
Under Age ☐

TRAINING PROGRAM FOR THE MASTERS GAMES

Commencement date _____

Intensity Easy ☐ Moderate ☐
Hard ☐ Very Hard ☐

Type of Exercise _____

Frequency _____ Times per week

Duration _____ Hours/Minutes

ou compete in Australian Masters Games in Tasmania, 1987 _____ Adelaide 1989 _____ Brisbane 1991 _____

YOUR SOCIAL PROFILE

Self Employed ☐
Full Time Employee ☐
Part Time Employee ☐
Home Duties ☐
Retired ☐
Unemployed ☐

employed
ou arrange to
e in the
Games?
Annual Leave ☐
Long Service Leave ☐
Leave Without Pay ☐
Other* ☐

our ocupation? _____

What is your gross annual income?

Up to $10,000 ☐
$10,000 to $20,000 ☐
$20,000 to $30,000 ☐
$30,000 to $40,000 ☐
$40,000 to $50,000 ☐
Over $50,000 ☐

What was the highest level of education completed?

Primary ☐
Secondary ☐
Tertiary ☐
Post Graduate ☐

l you be combining a holiday with your participation in the Masters Games? YES ☐ NO ☐

YOUR MEDICAL PROFILE

Title _____ First Name _____ Last Name _____

Home Address _____ Phone No. (H) _____

_____ Post Code _____ Phone No. (W) _____

Doctor's Name and Address _____ Are You a member of a private health fu
Yes ☐ No. ☐

_____ Post Code _____ Which? _____

FAMILY HISTORY	ILLNESS(ES)	CAUSE OF DEATH AND AGE AT DEATH (if appropriate)
Father		
Mother		

Do you suffer from any medical illnes?
(Particularly Heart Disease, High Blood Pressure, Diabetes, Epilepsy, Asthma)

_____

_____

_____

Do you suffer from any form of Arthritis? YES ☐ NO ☐

Please tick:

Osteoarthritis ☐ Rheumatoid Arthritis ☐

Other _____

Surgical Operations

_____

_____

_____

Have you ever had a joint replacement? YES ☐ NO ☐

If Yes, date: _____

Details: _____

_____

Injuries and Accidents

_____

_____

_____

Do you have a physical disability that requires you to use a walking aid, e.g. walking stick, crutches, wheelchair?

_____

Medication (and dosage)

_____

_____

_____

When did you last undergo a complete physical examination b
medical practitioner? Please tick:

Less than 12 months ago ☐ Approx. 2 years ago
In the last 2-5 years ☐ More than 5 years ago
Never ☐

Have you ever sustained a major injury as a result of playing sp
If yes, date 19
Details: _____

_____

Allergies:

_____

_____

Smoker (and quantity) YES ☐ NO ☐

Ex-Smoker YES ☐ NO ☐

When did you quit? _____

How many per day did you smoke? _____

Alcohol (and quantity) YES ☐ NO ☐

Ex-Drinker YES ☐ NO ☐

When did you quit? _____

Amount per day when you quit? _____

Symptoms (currently experienced)

Chest Pain	YES ☐	NO ☐
Breathlessness	YES ☐	NO ☐
Cough	YES ☐	NO ☐
Palpitations	YES ☐	NO ☐
Dizziness	YES ☐	NO ☐
Faints, fits or funny turns	YES ☐	NO ☐
Fatigue	YES ☐	NO ☐
Pain - Back	YES ☐	NO ☐
- Neck	YES ☐	NO ☐
- Joints	YES ☐	NO ☐
- Other	YES ☐	NO ☐

Details of above _____

_____

_____

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APPENDIX 3.

7th April, 1993

Dear

The Department of Human Movement at Edith Cowan University, in collaboration with the Endocrinology Department of Queen Elizabeth II Medical Centre, is currently researching the effects of exercise on muscle strength and bone density. The next step in this research is to study the effects of extended training histories on bone density and muscle strength.

Aging usually involves a loss of muscle strength and bone density, particularly after menopause. The aim of this research is to study if a lifetime of physical activity limits these losses occurring. The 1993 Masters Games offers a good opportunity to research this question.

As a result of the Confederation of Australian Sport questionnaire, you have been identified as a possible subject. The tests involved are simple, painless and non-invasive. Muscle strength is assessed by simple arm and leg contractions and bone mineral density is measured by Dual Energy X-ray Absorptiometry (DEXA). The total radiation dose of one DEXA scan is approximately 1/100 of that used in an ordinary X-ray, and is considered negligible by the National Health and Medical Research Council. All results of tests will be freely available.

Tests would be conducted during the evenings or weekends at Queen Elizabeth 11 Medical Centre during April and May 1993. Total testing time would be approximately 45 minutes.

Thank you for taking the time to read this letter. If you are interested in taking part in this study, will you please complete the attached questionnaire and return to the Department of Human Movement, Edith Cowan University, Joondalup Campus. If you have any questions regarding this project, please call Jan Dook on 387 6029 (Home) or Colin James on 405 5642 (Work), 496 1280 (Home).

Yours sincerely

JAN DOOK
DEPARTMENT OF HUMAN MOVEMENT

APPENDIX 4

.CRITERIA:

1. Pre-menopausal; Age 42 years and above
2. Have participated in your sport for over 20 years
3. Active; have maintained a moderate (to high) level of activity in your sport.
4. Non-smoker.
5. Social drinker only.

QUESTIONNAIRE

1. NAME: _____
2. D.O.B / AGE: _____
3. CONTACT ADDRESS/PHONE: _____

_____

_____

MENSTRUAL HISTORY:

Do you still menstruate? _____

If not, when was your last menstrual period?

_____

If not, have you had a hysterectomy? _____

Are the ovaries still intact? _____

Have you had any symptoms of menopause? _____

If so, when and for how long? _____

Do you receive any Hormone Replacement Therapy? _____

Do you smoke? _____

If so, how many / day? _____

Have you ever been a smoker? _____

If so, at what age, and how many did you smoke / day? _____

TRAINING HISTORY

Under the following age groups, could you briefly indicate what activities you were involved in at that age and approximate time spent per week
eg. 13 years - 16 years: netball; 3 hours, Basketball; 8 hours

6 years - 12 years
13 years - 16 years
17 years - 20 years
21 years - 25 year
26 years - 30 years
31 years - 40 years
41 years - 50 years
51 years plus

Rate your involvement in sport and exercise during your life?

- Very Involved ☐
- Involved ☐
- Recreational ☐
- Minimal ☐
- Rarely Involved ☐

What was the highest level you achieved in your sporting career?

_____

APPENDIX 5.

CONSENT FORM

The aim of this research is to study if a lifetime of physical activity limits loss of muscle strength and bone mineral density normally associated with aging.

It is hoped such research may benefit females by encouraging adolescents to participate in and develop life-long practices of physical activity.
It may also benefit community groups by providing guide-lines to the type of activity suitable for muscle and bone health.

1. MUSCLE STRENGTH

Assessment is by simple arm and leg contractions using a strength chair.

2. BONE MINERAL DENSITY

Measurement is by Dual Energy X-ray Absorptiometry (DEXA). The total radiation dose of one DEXA scan is approximately 1/100 of that used in an ordinary X-ray, and is considered negligible by the National Health and Medical Research Council.

3. CALCIUM INTAKE

A 'Food Frequency' questionnaire is used to determine calcium intake.

The results of all of your tests will be freely available to you and will be forwarded in due course. Data will however be regarded as strictly confidential and anonymity preserved at all times.
Your participation in this study is appreciated. You do of course have the right to withdraw at any time, for any reason.

SIGNED: _____

DATE: _____

APPENDIX 6.

SPECIAL PRECAUTIONS PROCEDURE

* QUESTIONNAIRE FOR PREMENOPAUSAL VOLUNTEERS BEFORE SPINAL OR FEMORAL NECK QDR SCAN

ATIENT ID No: _____

AME: Family name _____ Other names _____

1. What is the date of onset of your last menstrual period? _____

2. Is your period overdue? YES NO
   If YES, by how many days _____

3. Is there any possibility that you may be pregnant? YES NO

I _____ declare that to the best of my knowledge there is no possibility that I may be pregnant.

VOLUNTEER'S SIGNATURE _____

OPERATOR'S SIGNATURE _____

DATE _____

Basketball/ Netball.

ID	TRAIN	AGE	HT	WT	BMD	ALC	BICEPS	QUADS	% FAT	BMD	BMD	LEAN	HRS ACTIVITY			Ca++
	years	years	cm	kg	g/cm2	units/wk 1=200ml	newton	newton		LEG MEAN	ARM MEAN	MASS gram	13-20	20-30	30-45+	mg/day
MA01	30.0	51.0	165.0	64.5	1.191	1.0	248	408	31.1	1.194	0.736	41567.2	-	-	-	408.6
MA05	25.0	47.0	171.0	67.5	1.160	2.0	278	382	23.2	1.211	0.761	48478.2	8.0	6.0	6.0	1025.8
MA07	32.0	48.0	169.0	56.0	1.158	4.0	48	-	24.4	1.193	0.755	39460.6	6.0	2.5	4.0	734.9
MA08	33.0	48.0	167.0	67.5	1.135	4.0	31	440	36.6	1.230	0.718	40260.7	8.0	8.0	2.5	466.0
MA09	30.0	49.0	168.3	75.6	1.065	1.0	-	206	35.8	1.206	0.707	44939.6	4.0	1.5	3.5	675.9
MA11	20.0	41.0	154.0	55.0	1.115	1.0	214	247	36.2	1.209	0.711	32650.3	-	-	-	1445.0
MA15	35.0	48.0	172.0	68.5	1.252	7.0	266	484	29.5	1.346	0.770	44790.8	4.5	1.5	6.0	1170.4
MA18	20.0	46.0	167.5	61.0	1.172	1.0	240	330	24.0	1.229	0.699	43148.8	7.0	5.0	6.0	1719.7
MA20	43.0	50.0	162.0	63.7	1.069	0.0	-	-	32.7	1.139	0.725	40129.7	10.0	8.0	6.0	559.8
MA23	40.0	48.0	162.5	75.6	1.184	56.0	191	252	43.3	1.162	0.799	39891.4	-	-	-	513.4
MA31	20.0	47.0	172.0	69.0	1.111	6.0	236	362	28.5	1.151	0.737	45835.5	7.0	5.0	2.0	764.1
MA32	25.0	44.0	151.0	48.8	1.034	7.0	127	159	24.7	1.076	0.654	34346.7	7.0	10.0	1.0	1313.0
MA33	30.0	45.0	168.5	55.0	1.077	0.0	224	326	20.8	1.121	0.684	40370.3	3.5	4.0	7.0	575.6
MA35	30.0	44.0	162.0	68.3	1.107	0.0	210	332	40.6	1.153	0.650	37650.4	1.5	4.5	8.0	633.6
MA41	30.0	42.0	174.5	73.1	1.015	1.0	284	390	36.6	1.108	0.711	43683.5	7.0	8.0	10.0	820.8
MA45	30.0	42.0	163.5	67.2	1.121	7.0	-	-	36.1	1.197	0.700	40265.1	7.0	2.0	8.0	983.1
MA46	30.0	40.0	171.0	75.9	1.375	5.0	235	503	31.9	1.447	0.856	47996.8	7.0	5.0	6.0	276.4
MA53	25.0	47.0	166.0	58.0	1.181	3.0	-	-	18.5	1.115	0.712	44165.0	1.5	2.0	5.0	216.8
MA57	30.0	42.0	171.5	67.8	1.245	5.0	235	305	26.4	1.324	0.806	46290.8	6.0	4.5	14.0	821.9
MA65	30.0	42.0	169.5	72.1	1.227	0.0	247	507	37.7	1.246	0.773	41694.5	15.0	5.5	4.0	1008.4
Mean	29.4	45.5	166.4	65.5	1.150	5.6	207	352	30.9	1.203	0.733	41880.8	6.5	4.9	5.8	806.7
SD	8.5	3.2	6.0	7.7	0.085	12.1	75	104	6.9	0.088	0.051	4131.5	3.2	2.5	3.1	391.2

Controls.

ID	TRAIN	AGE	HT	WT	BMD	ALC	BICEPS	QUADS	% FAT	BMD	BMD	LEAN	HRS ACTIVITY			Ca++
		years	cm	kg	g/cm2	units/wk 1=200ml	newton	newton		LEG MEAN	ARM MEAN	MASS gram	13-20	20-30	30-45+	mg/day
MA52		46.0	164.0	76.4	1.054	0.0	262	285	45.4	1.145	0.654	39339.9	1.0	3.0	0.0	350.9
MA51		47.0	169.5	71.1	1.178	4.0	159	270	34.8	1.111	0.781	42810.7	3.0	0.0	0.0	767.4
MA50		44.0	159.5	58.1	0.990	0.0	172	202	38.2	1.063	0.639	33462.7	1.0	1.5	2.0	523.2
MA28		48.0	157.5	57.2	0.987	0.0	195	335	35.9	1.083	0.618	34501.7	0.5	0.0	0.0	2614.3
MA27		46.0	165.5	53.5	0.998	7.0	182	324	30.9	1.018	0.656	34549.9	1.0	0.0	0.0	259.0
MA25		45.0	156.0	63.6	0.983	0.0	258	347	41.9	0.984	0.644	34534.0	1.0	0.0	0.5	1064.2
MA49		42.0	171.0	66.2	1.092	0.0	153	262	33.7	1.123	0.712	41020.3	2.5	1.0	0.5	874.0
MA34		50.0	163.0	64.3	1.033	3.0	229	210	40.6	1.118	0.695	35258.8	2.0	3.0	3.0	1134.3
MA48		44.0	171.5	65.6	1.022	7.0	155	290	32.7	0.995	0.669	41578.2	1.5	0.0	0.5	1399.8
MA56		44.0	166.7	68.7	0.980	0.0	198	225	40.0	1.037	0.646	38000.1	3.0	3.0	2.0	514.6
MA58		44.0	178.0	70.0	1.104	1.0	170	232	41.0	1.093	0.687	38054.6	3.0	0.0	0.0	583.0
MA54		44.0	167.0	72.0	1.103	1.0	258	327	38.9	1.101	0.658	41399.3	6.0	0.0	0.0	1166.7
MA 55		46.0	156.7	67.4	0.908	1.0	152	210	43.8	0.883	0.574	35916.6	1.5	0.0	0.0	241.5
MA64		43.0	148.7	54.9	1.100	0.0	164	296	43.8	1.087	0.621	28677.8	1.5	0.0	0.0	333.0
MA63		45.0	175.0	67.5	1.062	0.0	187	299	37.2	1.061	0.744	40222.3	0.0	0.0	2.0	209.1
MA62		49.0	165.7	71.5	0.892	0.0	179	230	42.3	0.880	0.710	38986.9	3.0	0.0	0.0	190.2
MA61		49.0	169.5	69.2	1.039	0.0	105	230	39.9	1.134	0.671	38863.6	1.0	0.0	0.0	667.1
MA59		46.0	174.5	78.9	1.015	1.0	202	245	45.0	1.060	0.608	41068.6	3.0	1.0	1.0	885.1
MA69		46.0	178.0	70.0	0.980	1.0	-	-	40.2	0.971	0.692	39356.2	4.0	0.0	0.0	599.4
MA72		44.0	153.7	67.7	0.963	0.0	-	-	47.0	0.979	0.636	33760.2	0.0	3.0	3.0	979.6
Mean		45.6	165.5	66.7	1.024	1.3	188	268	39.7	1.046	0.666	37568.1	2.0	0.8	0.7	767.8
SD		2.1	8.2	6.7	0.070	2.2	42	47	4.4	0.077	0.048	3598.8	1.5	1.2	1.1	562.0

Swimming.

ID	TRAIN	AGE	HT	WT	BMD	ALC	BICEPS	QUADS	% FAT	BMD	BMD	LEAN	HRS ACTIVITY			Ca++
	years	years	cm	kg	g/cm2	units/wk 1=200ml	newton	newton		LEG MEAN	ARM MEAN	MASS gram	13-20	20-30	30-45+	mg/day
MA30	30.0	48.0	167.0	60.0	1.050	1.0	190	-	17.4	1.124	0.688	46713.3	6.0	7.0	10.0	495.3
MA04	30.0	51.0	169.0	65.5	1.082	5.0	174	308	31.9	1.084	0.728	42031.9	1.0	1.0	9.0	294.4
MA03	-	55.0	157.0	68.8	0.968	0.0	244	312	34.9	1.034	0.694	42347.0	6.0	4.0	6.0	1925.7
MA02	41.0	48.0	171.0	74.3	1.160	3.0	252	406	33.1	1.213	0.804	46225.3	2.0	4.0	4.0	834.9
MA17	30.0	45.0	165.5	75.2	1.286	4.0	173	339	33.0	1.283	0.808	46977.9	18.0	10.0	10.0	676.0
MA40	30.0	45.0	165.5	63.0	1.006	3.0	236	349	30.2	1.089	0.694	41199.0	7.0	2.0	4.0	320.6
MA24	40.0	47.0	165.0	105.5	1.092	4.0	250	370	42.4	1.207	0.733	57403.6	10.0	5.0	6.0	427.5
MA36	30.0	47.0	161.0	54.0	1.132	2.0	226	255	23.9	1.075	0.741	38244.7	8.0	2.0	3.0	697.6
MA39	-	43.0	161.0	53.3	1.096	7.0	225	308	15.2	1.120	0.718	42594.1	3.0	2.0	6.0	446.4
MA67	30.0	44.0	147.5	46.4	0.891	0.0	180	262	27.7	0.929	0.584	31781.5	21.0	7.0	8.0	1791.4
MA73	30.0	47.0	169.0	74.8	1.074	0.0	165	173	38.9	1.023	0.730	43093.9	6.0	5.0	4.0	1104.6
MA78	30.0	41.0	176.3	65.2	1.009	3.0	197	337	25.3	1.132	0.680	46136.5	7.0	4.0	3.0	795.4
MA68	20.0	44.0	167.0	56.6	1.062	5.0	127	285	27.3	1.014	0.649	38777.3	7.0	6.0	6.0	621.0
MA82	30.0	43.0	152.5	53.3	1.024	1.0	170	240	21.5	1.033	0.706	39621.0	6.0	8.0	10.0	2162.1
MA74	25.0	41.0	172.5	69.6	1.045	6.0	177	235	28.7	1.084	0.697	47043.2	10.0	3.0	2.0	646.2
MA81	20.0	50.0	153.0	54.3	0.986	4.0	143	240	35.5	1.020	0.638	33017.6	5.0	0.0	4.0	1305.5
MA77	20.0	45.0	166.5	64.2	1.154	3.0	183	314	29.9	1.226	0.753	42347.6	7.0	0.0	3.0	1223.3
MS70	30.0	`47	173.0	59.2	1.048	1.0	190	308	17.4	1.170	0.699	46234.6	12.0	5.0	15.0	1669.2
MA71	30.0	41.0	178.0	78.7	1.112	6.0	282	397	33.6	1.217	0.767	49403.3	18.0	16.0	9.0	1475.5
MA84	30.0	45.0	174.0	67.5	1.005	7.0	202	350	28.5	1.084	0.703	45745.0	23.0	14.0	18.0	481.2
Mean	29.2	45.8	165.6	65.5	1.064	3.2	199	305	28.8	1.108	0.711	43346.9	9.1	5.2	7.0	969.7
SD	5.6	3.6	8.2	12.9	0.084	2.3	40	60	7.2	0.090	0.053	5679.3	6.2	4.3	4.2	575.6

Generals.

ID	TRAIN	AGE	HT	WT	BMD	ALC	BICEPS	QUADS	% FAT	BMD	BMD	LEAN	HRS ACTIVITY			Ca++
	years	years	cm	kg	g/cm2	units/wk 1=200ml	newton	newton		LEG MEAN	ARM MEAN	MASS gram	13-20	20-30	30-45+	mg/day
MA44	34.0	42.0	167.0	60.0	1.139	10.0	-	-	24.2	1.161	0.742	42395.2	10.0	8.0	6.0	63.1
MA26	20.0	46.0	160.5	58.0	1.061	4.0	255	365	31.3	1.164	0.686	37118.4	4.5	12.0	15.0	1110.5
MA06	20.0	44.0	169.5	60.0	1.149	2.0	272	380	27.1	1.141	0.686	40742.0	0.0	4.0	17.0	1071.2
MA37	-	48.0	167.5	58.0	1.123	14.0	221	266	27.8	1.134	0.676	39202.8	-	-	-	813.1
MA43	30.0	45.0	153.5	61.5	1.116	4.0	213	280	34.6	1.204	0.695	36700.3	5.0	0.0	4.0	917.5
MA42	30.0	43.0	153.5	57.3	1.035	2.0	195	337	32.9	1.123	0.618	35937.2	3.0	4.0	4.0	558.4
MA38	30.0	46.0	170.0	57.0	0.999	4.0	160	270	19.2	1.098	0.654	43614.2	3.0	2.0	4.0	1466.8
MA29	-	48.0	160.0	63.3	1.131	21.0	240	357	32.8	1.248	0.731	39970.1	8.0	6.0	4.0	272.9
MA22	30.0	43.0	154.0	58.7	1.119	2.0	210	315	35.5	1.161	0.686	35402.7	-	-	-	867.4
MA21	40.0	52.0	174.0	65.0	1.054	5.0	247	356	25.1	1.095	0.657	45544.6	10.0	6.0	6.0	691.7
MA10	33.0	48.0	154.0	56.0	0.917	0.0	-	145	32.1	1.026	0.611	36019.8	10`	4.0	12.0	582.1
MA76	30.0	45.0	163.3	70.0	1.152	4.0	182	405	37.3	1.324	0.751	41156.5	10.0	8.0	2.0	906.2
MA79	30.0	49.0	170.0	61.1	1.144	14.0	270	360	24.5	1.191	0.769	43490.3	8.0	14.0	4.0	899.5
MA80	30.0	44.0	161.2	61.7	1.131	5.0	210	337	29.9	1.115	0.726	40652.2	11.0	3.0	7.0	638.8
MA75	30.0	47.0	160.7	63.3	1.065	7.0	154	292	36.1	1.157	0.738	38208.5	20.0	12.0	15.0	1222.4
MA83	27.0	40.0	174.5	78.8	1.253	5.0	224	375	35.2	1.247	0.790	47770.8	10.0	5.0	8.0	939.1
MA16	23.0	50.0	170.5	84.5	1.196	15.0	245	526	37.9	1.259	0.773	49149.7	3.5	6.0	12.0	623.1
MA13	32.0	48.0	164.0	54.5	1.377	0.0	166	325	21.9	1.434	0.795	39234.0	12.0	10.0	10.0	1555.1
MA19	-	51.0	157.5	65.0	1.058	0.0	138	227	39.0	1.149	0.705	37149.2	3.0	4.0	3.0	816.9
Mean	29.3	46.3	163.4	62.8	1.117	6.2	212	329	30.8	1.181	0.710	40497.8	7.6	6.4	7.8	842.9
SD	5.0	3.2	7.0	7.7	0.097	5.9	41	80	5.8	0.092	0.054	4004.6	4.9	3.8	4.8	363.9

APPENDIX 8.

OOD FREQUENCY QUESTIONNAIRE Study stage:_____ Code:

ame:_____ Date:_____

lease circle your response or fill in the space.

. What type of milk do you usually use?

Whole, Hilo, Nonfat, Calcium Plus

. How many cups of tea, coffee or substitute, with added milk, do you usually have per day? _____

. Do you add milk to breakfast cereal? Yes No

. How often do you eat cereal per week? _____

. What type of breakfast cereal do you usually eat? _____

. Do you have milk drinks? Yes No
e.g. cappuccino, flavoured milk, milk shakes, smoothies, plain milk.

If yes, How much per week? mls/wk

cappuccino (1=180mls) _____

flav. milk (1 sm carton =300mls) _____

milkshake (1=340ml) _____

plain milk (1 glass= 250ml) _____

other_____ _____

. How much milk in total would you consume per day? _____

8. What type of bread do you usually eat?
   white, wholemeal, rye

9. How much do you usually eat per day (1 slice=30g)? _____g/day

For the following questions please consider how many serves you would have per week. Then use the grams/serve information provided, to convert to grams per week.
If you eat something less than once per week, but at least once per month, please indicate the amount you would have per month
e.g. cheddar 50g/mth.

10. How much of the following cheeses do you usually consume per week? (Don't forget cheese in cooking)

		grams/week
(1sl=25g)	cheddar	_____
(1T=9g)	parmesan	_____
(1sl=20g)	processed	_____
(1T=20g)	cream cheese	_____
(1T=18g)	cottage	_____
Any other? _____		_____

How much of the following foods do you usually eat per week?

11.	Yoghurt (1 tub=200g)	_____
12.	Icecream (1 scoop=60g) (1 novelty=70g)	_____
13.	Custard (1/2 Cup=140g)	_____
14.	Soy milk: Brand_____	_____
15.	Eggs (1=50g)	_____
16.	White sauce (1/2 Cup=130g)	_____
17.	tinned salmon (1/2c=120g)	_____
	sardines (4-5=60g)	_____
	prawns (3-4=100g)	_____
	white fish (1 fillet=100g)	_____

How much of the following foods do you usually consume per week?

		grams/week
18.	sweet biscuits (1=15g)	_____
	cracker biscuits (1=10g)	_____
19.	spinach/silverbeet (1/3c=60g)	_____
	broccoli (1 serve=84g)	_____
	dried fruit (1T=15g)	
	type_____	_____
	_____	_____
20.	milk chocolate (1 square=5g) (1 bar=50g)	_____
	milo/ovaltine(1T=9g)	_____

21. Do you take any vitamin or mineral supplements? Yes No

If yes, please specify type, amount and frequency of use.

_____

_____

22. How much alcohol do you have per week?

	ml/wk		
Beer	_____	type _____	1 bottle=750ml, 1 stubbie=375ml 1 middie=285ml, 1 glass=200ml
Wine	_____	(1 glass=120ml)	
Spirits	_____	(1 nip=30ml)	
Sherry/ Port	_____	(1 glass=60ml)	

23. Are there any foods or drinks you are consciously avoiding while you are pregnant or breastfeeding?

Yes No

If yes, what?_____

_____

Why?_____

_____

24. Are there any foods or drinks you are consciously emphasising while you are pregnant or breastfeeding?

Yes No

If yes, what?_____

_____

Why?_____

_____

25. How many days per week do you usually eat meat, fish or poultry?_____

26. In the last 3 months have you attempted to lose or gain weight by changing your food and drink intake?

Yes No

If yes, what modifications have you tried?

_____

_____

_____

When did you start this?_____

How long did you try this for?_____

THANK YOU FOR TAKING THE TIME TO ANSWER THIS QUESTIONNAIRE