Centre of Exercise and Nutrition Science

Strength Training and Bone Mineral Density of Active Postmenopausal Women

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Strength Training and Bone Mineral Density of Active Postmenopausal Women

Abstract

Rationale: Osteoporosis is a global problem that affects one in three women and one in 12 men. More deaths are caused each year by osteoporosis than are caused by breast cancer, uterine cancer and ovarian cancer combined. Due to recent claims that exercise can help prevent and even treat osteoporosis, numerous studies have recruited people to be involved in many different types of exercise. However, no study has looked at the effect of a 15 minute strength training programme on already active postmenopausal women. The main focus of this study is to assess the benefit of adding three sessions of 15 minutes strength training to an already active population with low bone mineral density.

Methods: Initially 31 women were recruited for the study. However, due to numerous reasons 19 subjects completed the 12 week study. Bone mineral density was measured and the subjects were randomly assigned to either the control of exercise group. The exercise group completed 12 weeks of strength training (three sessions per week working at 80% of their 1 rep max) in addition to their normal activities. The control group continued their normal activities for the 12 week study. Exercise programmes were adapted every four weeks to ensure subjects were still working at the desired intensity. At the end of the study bone density was measured again and data assessed using SPSS for Windows, Release 13.0.

Results: The age range for this study was 46 years of age to 70 years of age. For the purpose of this study Low bone density was categorised as having T-scores below -1. All subjects with a t-score above -1 were excluded at the initial testing stage. Overall, mean bone mineral density for the control group was 91.83% ± 13.6 and for the exercise group was 85.19% ± 15.58. However, there was no significant difference between the two groups at the initial stage. Following the 12 weeks study the mean bone mineral density for the control group was 91.69% ± 11.176 and for the exercise group was 88.09% ± 19.62. There was found to be no significant change in bone mineral density for the control group at the end of the study. However, the exercise group were found to have significantly increased bone mineral density following 12 weeks of strength training (p = 0.002). In addition, the exercise group also showed significant strength increases following the study (p = 0.02).

Conclusion: This study has important, and positive, findings not only for individuals wishing to improve their bone density and quality of life, but also for health care professionals trying to reduce the huge £1.8 billion annual cost of osteoporosis related injuries. Although the results of this study are encouraging, more research is needed in this area.
This work is original and has not been submitted previously in support of any other degree or qualification.

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Section I – Introduction

Osteoporosis is a multifactorial disorder (Riggs, 1991); it is defined as a reduction in bone mass and deterioration of bone tissue which leads to increased susceptibility to fractures (Bemben & Fetters, 2000; Gunn, 1996; Peichl, 1996; Slattery, 1996). In other words bone tissue loses its mineral mass and becomes more porous and brittle. It can happen at any age and to anybody (Nelson & Wernick, 2000).

Osteoporosis usually reveals itself through back pain, loss of height, spinal deformities (dowagers hump), and fractures, usually of the hip, wrist and vertebrae (Riggs, 1991). The most common symptom experienced is back pain caused by vertical compression fractures (Riggs, 1991). In some cases, the occurrence of these fractures can be one or more per year (Riggs, 1991).

With aging, bones can become hazardously fragile. Many, especially elderly, people break bones resulting in pain, loss of independence and even death (Palombaro, 2005; Gallagher et al. 2002; Nelson & Wernick, 1998; Evans & Meredith, 1989).

Osteoporosis is a major public health problem due to its link with age related fractures (Gallagher et al. 2002; Helge & Kanstrup, 2002; Eiken et al. 1997; Peichl, 1996). Osteoporotic fractures can occur from moderate trauma, such as a simple fall (Peichl, 1996; Riggs, 1991). In some cases bones become so fragile that everyday activities such as lifting a baby out of a cot or even an enthusiastic hug may result in a break (Nelson & Wernick, 2000; Riggs, 1991), yet this does not need to be the case; osteoporosis “...is not inevitable and is preventable and treatable,” (Woolf, 1994). The prevention (and treatment) of osteoporosis is centred around adequate exercise and sound nutrition (Anonymous, 2004; Evans & Meredith, 1989) especially when started early in life; ideally before the menopause begins.

Holding body weight constant, there are several factors that contribute towards bone health. The three most important factors are nutrition, gonadal hormones and physical activity (Welch & Weaver, 2005; Volk, 2001; Wilmore & Costill, 1999; Heaney, 1996). These factors will be briefly considered here:
Nutrition: The skeleton is the body’s largest store of calcium (Petranick & Berg, 1997; Heaney, 1996). If intake of calcium is too low the bones will release calcium to ensure homeostasis is maintained (Petranick & Berg, 1997). Therefore, long-term low calcium intake may contribute to loss of bone mineral density (Petranick & Berg, 1997).

Gonadal Hormones: When women loose ovarian hormones, either through the menopause, anorexia or athletic amenorrhoea, the skeleton seems to sense that it has more bone than it needs (Heaney, 1996). It therefore allows re-absorption to carry away more bone than formation replaces (Heaney, 1996).

Physical Activity: The deterioration in functional capacity can decrease elderly peoples’ ability to perform activities of daily life (Rhodes et al. 2000). This reduced weight-bearing activity results in significant decreases in bone mineral density, confirmed by alterations in biochemical markers of bone turnover (Giangregorio & Blimkie, 2002). Beginning, and maintaining, a physically active lifestyle early on in life greatly increases ability to perform activities of daily life into old age (Nelson & Wernick, 2000).

In addition there are also a number of other factors that influence bone health such as smoking, alcohol abuse and certain types of medication, as well as the illness the medication is treating (Nelson & Wernick, 2000; Gunn, 1996; Heaney, 1996). The effects of each of these factors are independent of one another (Heaney, 1996). Thus, altering one factor will neither adversely affect nor compensate for the others (Heaney, 1996). For example, a high calcium intake will not overcome the effects caused by alcohol abuse.

As a result of osteoporosis becoming a major health concern there has been a great deal of interest in finding the best treatment. Aside from medication, one of the most promising strategies for preventing and treating low bone density is resistance exercise (Ross & Denegar 2001; Nelson & Wernick, 2000; Nelson & Wernick, 1998; Slattery, 1996). In studies conducted by Rhodes et al. (2000); Bemben et al. (2000); Nelson & Wernick, (2000); and Pruitt et al, (1992), a variety of intensities and durations were tested and the findings suggested that resistance exercise has a positive
effect on bone mineral density, however the most appropriate number of sets and repetitions has yet to be determined.

Women are said to be more vulnerable to osteoporotic fractures than men for two reasons. The first reason being the link between osteoporosis and the menopause (Ali, 2003; Wilmore & Costill, 1999; Petranick & Berg 1997). The menopause is a time when levels of hormones essential for reproduction decrease noticeably. It is thought that these decreases in hormones (namely oestrogen), cause changes to occur within the bone matrix (Eiken et al. 1997). Trabecular (inner bone) bone loss speeds up and cortical (outer bone) bone loss becomes evident (Nelson & Wernick, 2000; ACSM, 1995). The second reason being that women have a greater life expectancy than men (Volk, 2001; Griffin, 1990) and are therefore more likely to suffer from the age-related condition.

There are two types of osteoporosis (Riggs, 1991). Type I osteoporosis typically affects women 15 – 20 years after the menopause (Riggs, 1991), and is eight times more likely to occur in women than in men (Powers & Howley, 2001). Type I osteoporosis is characterised by a reduction in trabecular bone and results in fractures at sites with a high concentration of trabecular bone (Riggs, 1991). The most common sites for type I fractures to occur are vertebral fractures (usually “crush” type fractures associated with a loss in height and pain), distal ankle fractures and distal radius fractures (Powers & Howley, 2002; Riggs, 1991). The rate of trabecular bone loss in postmenopausal women with type I osteoporosis is two to four times greater than their counterparts without osteoporosis (Riggs, 1991). However, the rate of cortical bone loss is only slightly greater (Riggs, 1991).

Type II osteoporosis is found in those in the next age bracket: seventy and above. Type II osteoporosis results from slow bone loss over several decades (Riggs, 1991), and are twice as common in women as in men (Powers & Howley, 2001; Riggs, 1991). Sufferers of type II osteoporosis usually have bone density values for numerous sites of the skeleton in the lower section of the age adjusted “normal” range, (Riggs, 1991). This suggests that cortical and trabecular bone is lost at only a slightly higher rate than the mean loss for their aged-matched counterparts (Riggs, 1991). Hip and vertebral fractures are the main manifestations however, proximal humerus, proximal tibia and pelvic fractures are also common (Riggs, 1991).
Trabecular thinning linked with the slow bone loss of type II osteoporosis is responsible for the gradual, and usually painless, vertebral deformation known as "Dowagers Hump," (Riggs, 1991).

It is not just those aged fifty-five and above who are susceptible to the development of osteoporosis. Low bone mass has also been found in female athletes who experience pre-menopausal amenorrhoea, women with anorexia nervosa and those who have a genetic pre-disposition (Newsholme et al. 1994; Evans & Meredith, 1989). In all cases the low bone mass is said to be related to low oestrogen concentrations (Powers & Howley, 2001; Wilmore & Costill, 1999; Eiken et al. 1997; Newsholme et al. 1994; Griffin, 1990). Bone loss in the early twenties presents a serious problem for later life (Newsholme et al. 1994), as it is this bone mass that has to last into old age (Nelson & Wernick, 2000).

The occurrence of falls is partly related to impaired vision, the use of sedatives or other drugs, physiological weaknesses such as impaired balance, muscular weakness and slowed reaction time (Liu-Ambrose et al. 2004; Riggs, 1991). Around one third of community-dwelling elderly people fall at least once per year (Riggs, 1991). Exercise and physical activity are said to improve balance, muscular strength and alertness resulting in greater interdependency: hence improve quality of life (Anonymous, 2004; Ross & Denegar 2001; Powers & Howley, 2001; Nelson & Wernick, 2000; Slattery, 1996; Woolf, 1994). Furthermore, exercise and physical activity can have an influential effect on bone mineral density (Powers & Howley, 2001; ACSM, 1995). However, it has been well documented that the exercise must be weight bearing to have any effect on the bones and, only the bones actually involved in the physical activity will be affected (Nelson & Wernick, 2000). The build up of the bone will also be proportionate to the enormity and the frequency of the force applied (Nelson & Wernick, 2000). It would therefore seem that prescribing exercise for patients suffering from osteoporosis may decrease their chance of falling and subsequent fractures, enabling them to remain physically active and thus avoid bone loss through inactivity (Volk, 2001; ACSM, 1995).

Both osteoporosis and osteopenia are gaining more attention as diseases that must be prevented before they begin (Petranick & Berg, 1997). The aim, therefore of this study is to assess the effect of resistance training and calcium supplementation on
bone mineral density of post-menopausal women. Preventing osteoporosis is a life and death matter, just as preventing heart disease and cancer is.
Section II - Bone Changes

Bone is not a uniform tissue (Vermeer et al. 2004; Peichl, 1996). It is “...a dynamic tissue made of collagen, minerals and water,” (Volk, 2001). Like any structure, bone strength is dependant on its mass density, the arrangement of its material in space and upon the fundamental strength of its component material (Heaney, 1996).

In the adult skeleton there are two classifications of bone; cortical and trabecular (Petranick & Berg, 1997; Riggs, 1991). Cortical bone has a slower rate of turnover and is less metabolically active than trabecular bone (Riggs, 1991). Cortical bone makes up approximately 80% of the skeleton and is found mainly in the long bones (Petranick & Berg, 1997; Riggs, 1991). The remaining 20% is made up of trabecular bone, which is predominantly found at common osteoporotic fracture sites (Petranick & Berg, 1997), namely the spine, wrist and hip (Kanis et al. 1997).

During childhood and adolescence bone formation is greater than resorption (Welch & Weaver, 2005; Ross & Denegar, 2001; Ilich & Kerstetter, 2000). Physical activity in young people is associated with a larger bone mass (Evans & Meredith, 1989). Bone mass is thought to be at a maximum at around age 25 (Nelson & Wernick, 1997), 30 according to Ross & Denegar (2001). Between age 25 and 35, providing the individual is healthy, bone density will be maintained (Nelson & Wernick, 1997).

Age 35 is said to be a crucial point for bone health. From this point the natural tendency is to lose bone. If the appropriate measures are not taken to prevent this bone loss osteopenia will occur (Nelson & Wernick, 1997; Heaney, 1996). Osteopenia develops gradually over many years (Ross & Denegar, 2001). Cortical bone loss however is thought to be minimal until the menopause (ACSM, 1995).

During the first five years of the menopause (unless measures are taken to prevent this), bone will be lost at a rate of 1-2% (or maybe even more) per year (Ross & Denegar, 2001; Ilich & Kerstetter, 2000; Nelson & Wernick, 1997). This is the most critical time for preventative measures to be taken.

Around age 55 bone loss slows, however the loss can still be around 1% per year (Nelson & Wernick, 1997). Above the age of 70 bone loss slows again, but it is still lost at a rate of around 0.5% per year (Nelson & Wernick, 1997).
How is bone formed?

Bone density is determined by the actions of the osteoblasts and osteoclasts (Vermeer et al, 2004; Ross & Denegar, 2001; Riggs, 1991). Bone formation is a two-stage process of bone matrix synthesis and materialization carried out by osteoblasts (Bemben & Fetters, 2000; Petranick & Berg, 1997):

1. resorption phase – osteoclast cells are activated which breakdown and remove old bone
2. formation phase – osteoclasts are replaced by osteoblasts which deposit new bone

The bone remodelling cycle is a 4 – 6 month process (Bemben & Fetters, 2000). Petranick & Berg (1997), suggest this process can take anything from 6½ months up to eight months. The remodelling process of bone however, responds to different factors including mechanical loading and exercise (Petranick & Berg, 1997).

When force is applied to a bone, that bone bends or is deformed (ACSM, 1995). Bone responds to mechanical loading immediately. Furthermore only the bone under stress responds (Bemben et al. 2004; ACSM, 1995). When a bone is placed under strain a flow of events within the osteoblasts and osteocytes occur reflecting an adaptation to the imposed loading environment (ACSM, 1995; Evans & Meredith, 1989). However, the amount of strain placed upon the bone will affect the magnitude of the response (Anonymous, 2004; ACSM, 1995).

Bone mineral density decreases may be observed when there is a disruption in the balance between bone resorption and formation, i.e. when resorption rate is greater than formation rate (Bemben & Fetters, 2000).

Bone loss in the elderly is a slow process linked to the decreased osteoblastic activity (Riggs & Melton, 1992; cited in Bemben & Fetters 2000). In old bone the osteoclasts create a cavity that is not completely filled in by the osteoblasts (Bemben & Fetters, 2000). This bone loss mechanism affects both the cortical and trabecular bone (Bemben & Fetters, 2000).
Section III – Facts, Figures and Risk Factors

Osteoporosis is more common in women than in men (Wilmore & Costill, 1999). One in every three women and one in every twelve men in the United Kingdom will develop osteoporosis at some point during their life (Kanis & Glüer, 2000; Nelson & Wernick 2000). However once the age of 50 is reached these figures are even more disturbing (Kanis & Glüer, 2000). One in two women and one in four men will suffer from an osteoporosis related fracture in their remaining lifetime (Anonymous, 2004). It is a scary fact more women die each year from hip fractures than from breast cancer, uterine cancer and ovarian cancer combined (Nelson & Wernick, 1998).

Injuries and deaths related to falls are a major health care problem worldwide (Liu-Ambrose et al. 2004; Anonymous, 2004; Carter, et al. 2001). Approximately 30% of individuals aged 65 and over fall at least once each year (Liu-Ambrose et al. 2004). About half of these fall recurrently (Liu-Ambrose et al. 2004). The occurrence of fractures increases considerably with age (Petranick & Berg, 1997; Heaney, 1996).

The National Osteoporosis Foundation indicated that 1.3 million hip fractures in Britain each year are linked to osteoporosis (Bemben & Fetters, 2000). Hip fractures are one of the more devastating fractures (Liu-Ambrose et al. 2004; Kanis et al. 2002). About 15 – 20% of hip fracture patients will die as a result of their injury (Nelson & Wernick, 2000; Kanis et al. 1997; Heaney, 1996). Many more will lose their independence and quality of life (Nelson & Wernick, 2000; Riggs, 1991). However all fractures contribute to the burden of illness, disability and expense which both the elderly and society must bare (Heaney, 1996).

The most expensive osteoporosis related fracture is again the hip fracture (Petranick & Berg, 1997). As hip fractures require hospitalisation and a great deal of after care it has been estimated that hip fractures in the USA cost about $40,000 per case (Petranick & Berg, 1997). In the UK it is estimated that the annual cost to the NHS of osteoporosis related incidents ranges from £940 million (Royal College of Physicians, 1999; cited in The National Horizon Scanning Centre, 2003) to £1.8 billion (Burge et al. 2001; cited in The National Horizon Scanning Centre, 2003).
Almost all fractures occur as a result of some kind of injury that places a greater force onto the bone than it is capable of withstanding (Heaney, 1996). The most common cause of excess force application is a fall or incorrect lifting technique (Heaney, 1996; Peichl, 1996).

There are measures that can be taken to reduce the likelihood of developing osteoporosis (Anonymous, 2004; Ali 2003; Ross & Denegar 2001; Ilich & Kerstetter, 2000; Nelson & Wernick 1997; Petranick & Berg 1997):

1. Sedentary lifestyle – less active individuals are at greater risk than those involved in activity.
2. Menstrual Interruptions – Menstrual interruptions (apart from pregnancy) before the menopause increase the risk of developing low bone density.
3. Poor diet – both calcium and vitamin D are crucial for healthy bones.
4. Cigarette Smoking – Women who smoke have lower bone density. They also lose bone faster after the age of 40.
5. Drinking – drinking more than 2 units of alcohol per day interferes with calcium metabolism and therefore bone health.
6. Excessive consumption of protein and caffeine.
7. High blood pressure and salt intake.

Unfortunately there are also risk factors that cannot be avoided, no matter what (Welch & Weaver, 2005; Anonymous, 2004; Kanis et al. 1997; Nelson & Wernick, 1997):

1. Gender – women are at more risk than men.
2. Age – With age, risk increases.
3. Race – Lighter skinned individuals are at greater risk.
4. Family history – risk is increased if there is a family link, i.e. parents and/or grandparents.
5. Body type – The smaller the frame the greater the risk.
6. Early menopause – if the menopause is reached before the age of 45 (be it natural or via hysterectomy) the risk is increased.

The more risk factors individuals have stacked against them the more important prevention – including strength training – becomes (Nelson & Wernick, 1997).
Fracture Risks

The risk of fracture, and this does not just apply to osteoporosis patients, is related to three things (Peichl, 1996):

1. The likelihood of sustaining trauma.
2. The ability to dissipate the forces of the trauma.
3. The ability to resist the residual loads delivered to the skeleton.

Figure 1 below indicates this in more detail.

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**Figure 1: Risk of Fracture: Diagram from Peichl, (1996)**

Risk of falling is dependant on both neuromuscular and visual function, as well as the amount and type of environmental hazards individuals are exposed to (Carter *et al.* 2001; Peichl, 1996; Griffin, 1990). If an individual falls without adequate protection fracture risk will depend on bone strength (Nelson & Wernick, 2000; Peichl, 1996).

Due to the nature of this study the following risk factors will be considered in greater detail:

- Nutrition
- Hormones
- Physical Activity
Nutrition
The creation, maintenance and repair of bone tissue are the result of cellular processes (Heaney, 1996). The cells that perform this function are, like all other cells, dependant on nutrition (Heaney, 1996). Although calcium and vitamin D are not the only nutritional keys to the prevention of osteoporosis, they are by far the most critical (Anonymous, 2004)

At birth the human skeleton contains about 25-30 grams of calcium compared to the 1000 – 1500 grams contained in the average woman’s’ skeleton (Ilich & Kerstetter, 2000; Heaney, 1996). All this difference must come from the diet as the skeleton grows (Heaney, 1996).

Furthermore, unlike other structural nutrients such as proteins the amount stored is always substantially less then the amount ingested (Heaney, 1996). The reason for this is because the absorption efficiency of calcium is moderately low, even during growth (Heaney, 1996). Moreover, calcium absorption, and intake, is said to decline with age (Heaney, 1996; Riggs, 1991; Evans & Meredith, 1989), adding to the problem of bone health. To add to this calcium is lost each day through sweat, shed skin, hair, nails and in the urine (Heaney, 1996).

Calcium is essential to many of the body’s ‘behind the scenes’ chemical reactions. For example it is (Ali 2003; Nelson & Wernick 2000):
- needed for muscles to contract;
- needed to regulate blood pressure;
- needed to control bleeding.

If the amount of calcium obtained from the diet is inadequate the body is forced to draw upon the supply stored in the bones in order to continue these functions (Glenville 2005; Welch & Weaver, 2005; Ali 2003).

Pregnancy and during lactation may be times when the reserve of calcium in the skeleton is reduced (Glenville, 2005; Heaney, 1996).

During pregnancy the mother must provide enough calcium in order to maintain her own skeleton as well as for the creation of her baby’s (Heaney, 1996). During the nine months of pregnancy the mother provides the foetus with 25 – 30g of calcium. In the
nine months following the birth the mother provides a further 50 – 75g of calcium in her milk (Heaney, 1996). This equates to 7 – 10% of her own total body calcium, which, if it was not replaced, would result in a corresponding decrease in bone mineral density (Glennie, 2005; Heaney, 1996).

Calcium can be found in dark green vegetables, seeds, nuts, soya milk and dairy products (Ali 2003). It is also available from calcium fortified orange juice, tofu, salmon, rhubarb and many other sources (Nelson & Wernick, 1997).

The daily recommended intake of calcium is (Anonymous, 2004; Plant & Tidey, 2003; Nelson & Wernick, 1997):

Before Menopause:
- Not pregnant/breast feeding: 1000mg
- Pregnant/breast feeding: 1200 – 1500mg

Post Menopause:
- Not on HRT: 1500mg
- On HRT: 1000mg

While ingesting more calcium than needed will not produce more bone than the basic programme calls for (Ilich & Kerstetter, 2000), inadequate calcium intake does result in bone with a thinner cortex and thinner, fewer trabeculae (Heaney, 1996). It is reported that most people, especially young people, do not get anywhere near the recommended daily intake of calcium (Anonymous, 2004). In the USA 31% of children under the age of 5 do not get adequate amounts of calcium to build and protect their bones (Anonymous, 2004). By the time they reach their teenage years 88% of girls and 68% of boys are calcium deficient (Anonymous, 2004). This statistic is made all the more worrying by the fact that adolescence is the period of maximum bone growth, a period where adequate calcium consumption is vital (Anonymous, 2004; Nelson & Wernick, 2000)

Although calcium gets the majority of the attention with reference to osteoporosis it is not the only key nutrient for healthy bones (Nelson & Wernick, 2000; Newsholme et al. 1994). Vitamin D; although it gets little attention, is also essential for bone health (Anonymous, 2004; Ali, 2003). It assists calcium absorption by facilitating active transport (Heaney, 1996). Without vitamin D calcium is not absorbed properly
(Anonymous, 2004). The rate of age-related bone loss is reported to be inversely proportional to Vitamin D intake (Anonymous, 2004; Ali 2003; Heaney 1996).

There are two sources of vitamin D: Diet and the sun (sunlight triggers cells in the skin to manufacture the vitamin) (Nelson & Wernick, 2000).

Dairy products and oily fish both contain vitamin D (Ali, 2003; Heaney, 1996). Fortified milk and fortified cereal are thought to be the best sources of dietary vitamin D (Nelson & Wernick, 2000). However, most women don’t get enough vitamin D from food (Nelson & Wernick, 1997). In these cases the sun is the other option.

Vitamin D can be produced in the skin by “...a photochemical reaction in which ultraviolet light from the sun changes 7-dehydrocholesterol into previtamin D,” (Heaney, 1996). During summer being outside in the sun enables women to achieve their daily requirement in just 10 minutes (Nelson & Wernick, 1997).

In countries such as the UK, in winter it is hard to get enough vitamin D from the sun and it is often the case that women lose some bone density during the winter months (Nelson & Wernick, 2000). However, providing they are healthy and young, they will gain it all back during the summer (Nelson & Wernick, 2000).

Since bone is turned over at a rate of 8 – 10% per year, and only currently forming bone will be affected by current conditions, short term nutrition in isolation has a relatively small impact on current bone strength (Plant & Tidey, 2003; Heaney, 1996). It has been suggested however that nutrition may influence central nervous processing time or contribute to the general feebleness of individuals. Both of which influence the likelihood of falling, making overall nutrition a very important part of health (Heaney, 1996).

It is agreed that the best diet for both bone and general health includes both calcium and vitamin D, along with plenty of fresh fruits and vegetables (Nelson & Wernick, 2000; Heaney, 1996).
The Hormone Effect

Oestrogen controls the bone-dissolving activity of the osteoclasts. However, the menopause causes the ovaries to produce less oestrogen (Plant & Tidey, 2004; Petranick & Berg, 1997), which can be detrimental for two reasons. Firstly, the body’s ability to absorb calcium is diminished; and secondly the resorption of bone by osteoclasts begins (Ross & Denegar, 2001; Bemben & Fetters, 2000). The osteoblasts keep building; however, their efforts are outdone by the out-of-control osteoclasts. Overall, there is a net loss of bone (Ross & Denegar, 2001; Nelson & Wernick, 2000; Petranick & Berg, 1997).

The menopause is a time when trabecular bone loss accelerates and cortical bone loss becomes apparent (Shangold & Sherman, 1998; ACSM, 1995). Bone loss can be anywhere between 1% and 3% per year; even more in the first five years post-menopause (Bemben & Fetters, 2000; Nelson & Wernick, 1997; Petranick & Berg, 1997; Shangold & Sherman, 1998). In old age, especially in Caucasian and oriental women, this leads to osteoporosis (Evans & Meredith, 1989).

Oestrogen, one of the female sex hormones, is essential for maintaining bone mass in women (Plant & Tidey, 2004; Bemben & Fetters, 2000). Oestrogen also plays an important role in the response of bone to external loads (Bemben & Fetters, 2000). However, the exact mechanism by which oestrogen influences bone is not clear (Bemben & Fetters, 2000).

There are options available to women following the menopause to counteract loss of oestrogen production; this is known as hormone replacement therapy or HRT (Plant & Tidey, 2004; Kanis et al. 1997). However, the decision to begin HRT can be difficult (Nelson & Wernick, 2000). There is much conflicting evidence for both the pros and cons of this drug. The decision of whether or not to take HRT needs to be well researched before it is made (Nelson & Wernick, 1997).

What is the best thing to do? There is no simple answer to this question, however there are two general recommendations:

1. HRT involves both benefits and risks. These are not the same for everyone (Plant & Tidey, 2004). Taking HRT is a personal decision that should be made with the help of a very well informed doctor who knows the medical history of
the individual. What is right for one person does not mean it is right for everyone (Nelson & Wernick, 1997).

2. Whether a woman is taking HRT or not, strength and aerobic training will help protect both bones and the heart. Furthermore they are both virtually risk free (Glenville, 2005).

HRT has many benefits (Kanis et al. 1997; Petranick & Berg 1997):

- Significantly reduces the chances of developing osteoporosis.
- Protects against heart disease.
- Protects against Alzheimer’s.

Taking HRT for a few months/years during and following the menopause can ease normal menopausal symptoms e.g. hot flushes, mood swings, vaginal dryness and sleep disruptions. All these benefits last as long as HRT continues to be taken (Glenville, 2005).

However there are drawbacks too. Many women experience side effects such as (Nelson & Wernick, 1997):

1. Breakthrough bleeding
2. Water retention
3. Breast tenderness
4. Cramps

Also long term use of HRT can increase the risk of developing breast cancer (Plant & Tidey, 2003; Nelson & Wernick, 1997).

If a woman has a hysterectomy or undergoes the menopause before the age of 45 HRT is always advised as there is a very real risk of developing advanced osteoporosis in later life (Plant & Tidey, 2003).

Even if HRT is taken there is a need for physical activity too, as rather than just maintaining bone density it can actually be added to (Glenville, 2005; Nelson & Wernick, 1997).
Physical Activity

Once peak bone mass has been achieved the main forces that act on the skeleton are mechanical loads applied during everyday use (Heaney, 1996). As the population ages and becomes more sedentary (meaning that everyday forces are reduced), osteoporosis becomes more prominent (Helge & Kanstrup, 2002; Ross & Denegar, 2001). The most common causes of reduction in weight-bearing activity are bed rest; spinal cord injury; and loss of mobility due to balance impairment, muscular weakness, loss of confidence in walking, visual impairment (Giangregorio & Blimkie, 2002; Bemben & Fetters, 2000; Bemben et al, 2000; Nelson & Wernick, 2000; Petranick & Berg, 1997).

Age related losses in muscular strength are said to precede bone loss (Bemben et al. 2000). This may be because the lack of muscular force being placed on the bone causes a ‘disuse’ response to occur (Bemben et al. 2000). However the change happens so slowly it can go unnoticed until late on in life (Nelson & Wernick, 1997).

As well as bone loss, aging is also associated with balance problems that increase the risk of falling (Bemben & Fetters, 2000). Normally, when falling, the body is able to respond and get the arms into position to break the fall or get the body into a position where the buttocks can take the majority of the impact (Heaney, 1996; Riggs, 1991). Although these reflexes are almost always present in young people they often fail in the elderly (Heaney, 1996) making them unable to break their fall. This problem becomes more serious in an undernourished elderly individual who has less muscle and fat around the point of impact. Thus meaning they have less soft tissue over which the force can be dissipated; thus the bone takes the majority of the impact (Heaney, 1996).

If regular habitual weight-bearing activity is beneficial for maintaining bone mass it seems plausible that applying a load greater than body weight (i.e. resistance training) will bring out an even more favourable effect on bone mineral density (Weaver et al. 2001; Petranick & Berg, 1997). Weight bearing activities such as resistance training may have important extraskeletal benefits such as improving strength, coordination and balance and therefore reducing the likelihood of falling in the first place (Anonymous, 2004; Bemben & Fetters, 2000). Furthermore, conducting these
activities outside will also increase exposure to sunlight and in turn vitamin D (Anonymous, 2004).

It has been suggested that, "building bone mass is like putting money in the bank: the sooner you start, the more you'll have in later life," (Nelson & Wernick, 1997 p 53). However no matter what age the individual is there is a lot that can be done to protect bones (Nelson & Wernick, 1997).

Although there is no recommended daily allowance of exercise (Anonymous, 2004), the American College of Sports Medicine suggest that US adults should engage in 30 minutes, or more, of physical activity each day of the week (Lee & Paffenbarger, 1996). Exercise and physical activity are said to be contributing factors to increasing life expectancy and quality of life in older populations (Meliillo et al. 1996). Improving strength has been linked to improved bone mass, balance and mobility, all important for improving quality of life, (Rhodes et al. 2000).

Active women of all ages tend to have significantly more bone mineral than their sedentary counterparts (Petranick & Berg, 1997). Physical impact stimulates bone formation (Helge & Kanstrup, 2002; Nelson & Wernick 1997; Slattery 1996). The pull of muscle against bone, especially against gravity, works in the same way (Giangregorio & Blimkie, 2002; Nelson & Wernick, 1997). However, bone mineral density is said to increase only in areas of the body that are stressed by physical activity (Slattery, 1996). There is a strong, positive, relationship between the amount of muscle in a person’s body and the amount of bone (Nelson & Wernick, 1997; Riggs, 1991). This is why a total body resistance training programme is said to be beneficial for improving bone density. The stronger the muscles the more force they provide (Nelson & Wernick, 1997), thus the greater the reaction by the bone.

Resistance exercise not only builds bone it also cuts the risk of fractures by improving strength, coordination and balance which in turn reduce the risk of falling (Ross & Denegar 2001; Slattery 1996). Moreover, all these benefits come without any worrying side effects (Ross & Denegar 2001; Shangold & Sherman, 1998; Nelson & Wernick 1997).

A twelve-month study performed by Nelson & Wernick (1997) found that middle-aged women (number of subjects and exact age range was not specified) from the
local community who did not partake in exercise showed an 8.5% decrease in balance over the duration of the study. In contrast those who did partake in strength training actually improved their balance scores by 14% (Nelson & Wernick, 1997).

Research shows that non-weight bearing activity such as swimming is not as beneficial for bone health as medium or high-intensity activities such as walking or volleyball (Shangold & Sherman, 1998). However, in extreme cases swimming is better than no exercise (Shangold & Sherman, 1998).

It has been suggested by Bemben et al (2004) that, providing they do not induce exercise related amenorrhea, athletes whose training involves high strain magnitudes and strains applied in short duration (i.e. like resistance training), have the highest weight adjusted bone mineral density.

Therefore regular weight-bearing activity is thought to be beneficial for elderly people as it helps prevent bone loss, improves strength, balance and co-ordination which in turn reduces the risk of falling (Bemben et al. 2000).

It is thought that some of the changes commonly attributed to aging are in reality caused by disuse (Melillo et al, 1996). A lifetime programme of physical activity holds more promise for sustained health than any drug available today (Melillo et al, 1996). Unfortunately, there is still no conclusive evidence to say what is the most appropriate way of using resistance training to negate the negative effects aging has on bone mineral density.
Section IV – What the Research Suggests

Rhodes et al (2000) performed a study where 44 healthy females subjects, all between the ages 65 and 75, volunteered to take part in their study. They were randomly assigned either the control or the exercise group: 22 in each.

The subjects in the exercise group were involved in a fully supervised three-month whole body, training programme (1 hour, three times a week), aimed at strengthening large muscle groups. Following the initial three months the subjects continued the exercise programme (3 sets, 8 reps) on their own for a further nine months. The weights lifted were adjusted every two weeks and training supervisors often visited the subjects to check on correct technique. From the logbooks kept by the subjects compliance to the exercise programme was said to be 85%.

The control group were asked not to exercise but to continue with their normal lifestyle.

Bone density was measured before the 12-month exercise programme began using dual energy x ray absorption, and again at 12 months, and strength was measured from grip strength using a hand held grip dynamometer.

Although no statistically significant results were found, the general trend indicated an increase in bone mineral density for the exercise group and a decrease for the control group. The researchers suggested that long term (i.e. over a few years) structured exercise programmes may have an increased effect on bone density. As for strength, the exercise group showed a significant increase compared to the control group (p<0.01). This strength increase is thought to increase functional capacity, slow the progression of osteoporosis and lead to a better quality of life for the elderly.

Lord et al (1995) conducted a study where 197 women all aged between 60 and 85 years of age participated in a year long exercise trial. All the subjects were randomly recruited from the nearby community in Sydney.

The subjects were randomly assigned to either the exercise or the control group. Measures of balance and strength were taken at the beginning, mid point and end of the trial. At the end if the study the exercise group showed improvements in strength,
neuromuscular control and body sway. The control groups showed no significant improvements in any of the tests.

Pruitt *et al* (1992) conducted a study where 27 postmenopausal women, 17 in the exercise group and 10 in the control group, (the groups were matched so bone mineral density was similar between the two groups), performed a weight-training programme three times per week.

The exercises used involved both free weights and exercise machines, and targeted muscle groups that attached at or close to skeletal sites where bone mineral density was measured.

One set of 10 – 12 repetitions of upper body and 10 – 15 repetitions for lower body was performed at 60% 1 repetition maximum (60% 1RM).

After nine months strength had significantly increased for the exercise group and bone mineral density had also increased in the lumbar region of the spine by $1.6 \pm 1.2\%$. The control group on the other hand actually experienced a loss in bone mineral density of $-3.6 \pm 1.5\%$. Significance level was set at $p<0.01$.

There was no increase in bone mineral density in the femur or distal forearm of the exercise group.

Diet and hormonal status of all the subjects was measured and did not significantly differ between the two groups. Neither was considered a reason for the differences seen in the lumbar region of the spine.

They concluded that the decline in bone loss of the lumbar spine was due to the weight training. However, the lack of effect on the forearm and femur may have been due to the fact that both these regions are high in cortical bone, which takes a longer time to exhibit change due to it being metabolically less active.

Bemben *et al* (2004) performed a six month study where 26 female university level athletes; either gymnasts or cross-country runners, were recruited. During the study three gymnasts and one cross-country runner withdrew from the study due to injury.
The subjects ages ranged from 18 – 22 and were actively participating in all their team training sessions.

The study was designed to assess the difference in bone mineral density between the groups based on the type of mechanical loading to which they are accustomed to.

As part of their normal training the gymnastic group ran occasionally for aerobic fitness, weight trained 3-4 times per week and participated in gymnastic apparatus practice 6 days per week, and the cross-country group ran 6 times per week covering more than 40 miles each week. They did minimal strength training that consisted of mainly lower-body workout.

Dual Energy X-Ray Absorptiometry (DEXA) was used to measure the bone mineral density of the athletes both at the beginning and end of the study. Numerous sites were measured.

The gymnasts had significantly higher pre and post-test bone mineral densities at all the measured sites, however neither group experienced significant changes in bone mineral density at any of the sites tested.

Although not significant the cross-country runners showed a slight decrease in bone mineral density across all the sites from baseline measurements to the post-test measurements.

The gymnasts also exhibited non-significant changes. They had slight bone mineral density increases in total body, hip, femoral neck and trochanter and slight decreases in the spine and Ward’s area.

Liu-Ambrose et al. (2004) recruited women aged between 75 and 85 who had been diagnosed as having osteopenia or osteoporosis.

Before the 25-week study began all participants underwent bone mineral density screening using Duel Energy X-Ray Absorptiometry. Those with confirmed low bone density were invited to take part in the study.
Before the study began all women were examined by a physician to make sure they were fit to exercise. Ninety eight women were accepted onto the study. The women were randomly assigned to one of three groups: resistance training, agility training, or stretching.

The exercise began 1 week after the baseline measurements to assess fall risk were taken. Women were asked to attend their assigned class twice a week for the 25 weeks of the study and keep an attendance log of the classes and a fall log.

All the classes were 50 minutes long and included a 15 minute warm up, 20 minutes of core content and a 15 minute cool down. The head instructor recorded attendance.

The resistance training exercises included bicep curls, tricep extensions, seated row, lat pull down, mini squats, mini lunges, hamstring curls, calf raises, gluteus maximus raises on a mat. The training intensity was set at 50 – 60% of 1RM, with two sets of 10 – 15 repetitions being performed. By week 4 this intensity had progressed to 75 – 85% 1RM with two sets of 6 – 8 repetitions being performed.

Agility training involved ball games, relay races, dance classes and obstacle courses.

The stretching class consisted of stretching, deep breathing and relaxation techniques as well as general posture training.

The study found that resistance and agility training were more effective than stretching at reducing the risk of falling in the older population. After the 25-week programme both the resistance training and the agility training groups had significantly reduced their fall risk scores by 57% and 48% respectively. The stretching group had managed only a 20% reduction.

Bemben et al (2000) conducted a study where 25 healthy, postmenopausal, oestrogen-deficient women, all aged between 41 – 60 years, completed a six-month resistance-training programme. All those involved did so on a voluntary basis.

Subjects were matched according to the results of the first bone mineral density tests and then randomly assigned to either the high load; high repetition; or control group.
The exercising groups completed their set programme on three (non-consecutive) days each week for the duration of the study. The exercises were all performed under supervision and training logs were kept each session.

Each time a subject performed the exercises with ease the weight lifted was increased by the supervisor. The high repetition group progressed more quickly than the high load group due the lighter loads. By the end of the study the average training volumes for each exercise were 30% greater for the high repetition group compared to the high load group. However, there were no significant changes in bone mineral density observed.

Although it is generally accepted that high loads result in greater strength and bone mineral density improvements, this study actually reported a similar increase in strength between the two exercising groups and a trend of reduction in bone mineral density for the high load group.

Whilst providing similar health and fitness benefits, a lower intensity training programme may be more easily tolerated by the older population. This type of programme may also be more suitable to those suffering from osteoporosis and osteopenia whose weakened bones may not be able to withstand the stress of high-intensity resistance training (Bemben et al. 2000).

In general, studies indicate that bone mass can be affected by engaging in physical activity. However the question is, which type of exercise is most beneficial for reducing bone loss or increasing bone mass. The aim of this study is to assess the effect of high load resistance training on bone mineral density.

Hypotheses for this study are as follow:
\( H_1 = \) Strength training will have a positive effect on bone mineral density of post menopausal women.

\( H_0 = \) Strength training will have no effect on the bone mineral density of postmenopausal women.
Section V – The Study

Many members join health clubs so they can swim, take part in aqua aerobics and spinning classes or even just have massages in the spa. For this reason a letter was sent to Old Hall Country Club and Spa (see appendix A) on October 18th 2005 informing them about the nature of my study and asking their permission to conduct it within their Health Club. Permission was granted and on Thursday 16th, Friday 17th and Saturday 18th February 2006 three days of heel ultrasound tests were performed at Old Hall Country Club and Spa. Over the three days 64 individuals were tested. The subjects were recruited via posters situated around the club (see appendix B).

The Test

Bone mineral density can only be assessed via a diagnostic test (Kanis et al. 2002). Dual Energy X-Ray Absorptiometry (DXA or DEXA) is the best test available (Khaw et al. 2004; Nelson & Wernick, 1997) for determining bone mineral density. However, obtaining one of these machines was not feasible. For this reason bone mineral density was tested using a CUBA McCue heel quantitative ultrasound scanner (or QUS), which has been shown to be a reliable indicator of bone density (Cook et al. 2005; Zochling et al. 2004; Dolan et al. 1998) and fracture risk (Khaw et al. 2004). QUS is extremely portable, painless, easy to use, gives results instantly and even more importantly is free from radiation, as it uses sound waves rather than X rays to measure bone density (Khaw et al. 2004).

Of the 64 subjects tested initially 29 were excluded for reasons such as gender, time restrictions, inappropriate T-scores and unwillingness to take part in resistance training (for the full list of inclusion and exclusion criteria please see appendix C). All subjects who met the inclusion criteria were offered the chance to take part in the second phase of the study; the control or exercise group. All those who agreed to take part were informed about all aspects of the study and asked to read and sign an informed consent form (appendix D) and fill in a pre exercise questionnaire (appendix E), before the second phase of the study began.

There were 35 subjects who matched the inclusion criteria and wanted to take part in the second phase of the study. Of the 35 women four failed to return the informed consent and exercise questionnaire and were therefore excluded leaving 31 women.
These 31 women were randomly assigned to one of two groups, the control group (n=15) and the exercise group (n=16).

The control group were asked to continue as normal. They were asked not to make any changes to their lifestyle, diet or exercise routine for the duration of the study.

The exercise group were also asked to carry on with their normal lifestyle and exercise routine. In addition to this they were asked to perform five resistance training exercises three times per week.

The Programme

In the two weeks following the bone density scans the 16 subjects in the exercise group were set a resistance training programme by myself (an example of which can be found in appendix F). Each individual was asked to perform a variety of strength tests to determine their "1 rep max" (1RM) for five exercises. From these results a programme was devised working at 80% (or as close as possible to 80%) of their 1RM for each of the exercises. Participants were asked to perform eight repetitions of each exercise three times per week. Participants were also instructed to increase the repetitions (up to a maximum of 10) or weight as the exercises got easier.

The participants were left to do the programme on their own, however, all participants were given a phone number and e-mail address so they could contact the researcher should any questions, problems or concerns have arisen. In addition to this Old Hall Country Club and Spa has one or more fitness instructors present in the gym at all times.

Every four weeks the participants were met to review their programme. Where this was not possible they were contacted via telephone to assess their progress. Participants were encouraged to keep progressing their programme as it became easier to ensure they remained working at 80% of their 1RM throughout the study.

At the end of the 12 week study final strength tests were performed to assess any gains in strength as well as a repeat heel ultrasound scan of all participants in both groups.
Section VI - Results

Of the 64 subjects tested initially 29 were excluded for reasons such as gender, time restrictions, inappropriate T-scores and unwillingness to take part in resistance training. See figure 2 below for a full breakdown of initial exclusions.

Figure 2: Reasons for Exclusion

The most common reason for exclusion was inappropriate T-scores (N = 11; 38%). The study was aimed at improving bone mineral density in post menopausal women with low bone mineral density. Low bone density is categorised as having T-scores below -1 (Nelson & Wernick 2000). For this reason people with T-scores above -1 on both legs were excluded from the study.

The second highest exclusion category was time restrictions (N = 6; 21%). All subjects involved in the exercise phase of the study were required to complete their exercise programme three times each week. As people were randomly assigned to the groups there was no guarantee they were going to be in the control group, and could not commit to the required number of exercise sessions.

17% (N = 5) of subjects were eligible for the study but were unwilling to do resistance training for fear of getting "bulky." A further 4 (N = 2 in each group) people were excluded due to gender restrictions and becoming injured in the week...
between bone testing and the start of the 12 week study period. Finally 10% (N = 3) of subjects fit all other inclusion criteria but were excluded when it was discovered they were taking hormone replacement therapy.

A further 4 people were excluded on day one of the study as they failed to return their informed consent and pre exercise questionnaires leaving 31 subjects for the study. The pre test bone densities of the 31 subjects who agreed to partake in the study are shown in figure 3 below.

![Bone Density of Original 31 Subjects](image)

**Figure 3: Pre Test Bone Densities of the Original 31 Subjects**

The 31 subjects were then split into two groups: Exercise and control. The bone densities of the subjects in their respective groups can be seen in figure 4 on page 30. In addition, the control group age ranged from 46 to 70 years and the exercise group from 48 to 70 years on the day their bone mineral density was assessed.
Figure 4: Original Subjects Bone Density Results – Control & Exercise Groups

Of the 31 individuals who originally embarked upon the study only 19 completed the 12 week study (eight from the control group and 11 from the exercise group) and returned for final bone density scans (the mean pre study bone density values for the two groups can be seen in Table 1 below). The data were analysed using SPSS for Windows, Release 13.0 (2004).

Table 1: Mean Values for Bone Mineral Density of the Control & Exercise groups

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Minimum (%</th>
<th>Maximum (%)</th>
<th>Mean (%)</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Group Bone Density (Right &amp; Left Combined)</td>
<td>30</td>
<td>72</td>
<td>121</td>
<td>91.83</td>
<td>13.600</td>
</tr>
<tr>
<td>Exercise Group Bone Density (Right &amp; Left Combined)</td>
<td>32</td>
<td>55</td>
<td>118</td>
<td>85.19</td>
<td>15.582</td>
</tr>
<tr>
<td>Valid N (listwise)</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A one way ANOVA test was also performed (results in appendix G) to make sure there was no significant difference in bone mineral density between the groups. This result shows that overall, mean bone density was not significantly different between groups.
Figures 5 & 6 show the pre and post test bone density scores for the control and exercise group respectively.

**Figure 5: Control Group Bone Density Results**

**Figure 6: Exercise Group Bone Density Results**
In order to decide whether parametric or non-parametric tests needed to be used to analyse the data normality needed to be determined. As the sample size was less than 50 the Shapiro-Wilk test was used to determine whether the distribution of both the control group and exercise group bone densities had a normal curve. The data was found to satisfy this criteria as \( p > 0.05 \) (Appendix H), meaning parametric tests can be used.

Histograms were also generated to show the normality of the distribution for each group (Appendix I).

An independent samples t-test was then used (see appendix J) to assess pre test differences between the left and right leg bone densities for the whole group. There was again found to be no significant differences between left and right leg bone density \( (p > 0.05) \).

The subjects results were then split into their respective groups (control and exercise) and bone density was again assessed this time using a paired samples t-test. The first group considered was the eight subjects of the control group. Right and left leg values were combined and a paired samples t-test was performed on the pre-test and post-test bone density values (see appendix K). There was found to be no significant difference between pre and post study bone density results of the control group.

In order to get a definitive result the control group results were split into right and left leg results and another paired samples t-test was performed on pre and post study scores (see appendix L).

Again no significance difference between the pre and post study bone densities was found when the control group scores were split into left and right legs.

The same sets of tests were performed on the results of the 11 members of the exercise group. Firstly the right and left leg bone density values were combined and a paired samples t-test was performed to determine any significant differences between the pre study results and the post study results (see appendix M).
This time there was a significant difference between pre and post study values \((p = 0.002)\). As for the control group the results were further sub-categorised into left and right leg values and another paired samples t-test performed (see appendix N).

As shown in appendix N there was again a significant difference seen in both left and right leg values \((p<0.05)\).

As the exercise group were asked to participate in a 12 week strength training programme it is important to assess any changes in strength that may have occurred as a result of the programme. Figure 7 below highlights the change in 1 RM observed in the exercise group when they were tested pre and post study (individual subject graphs can be seen in appendix O).

![1RM Strength Changes: Pre & Post Study](image)

**Figure 7: 1RM Changes in the Exercise Group Pre & Post Study**

Figure 8 on page 34 shows, at a glance, strength increases for each of the participants involved in the study.
However in order to see if there has been any significant increase in strength during the study a paired samples t-test would need to be performed on the results. Before a t-test test can be performed the data must first be checked for normality (Appendix P).

Appendix P shows the strength of the exercise group follows a normal distribution (p = 0.268). Thus meaning parametric tests can be used to assess the changes in strength. Appendix Q shows the results of the paired samples t-test used to assess significant strength changes of the subjects. It can be seen that there is a significant increase in strength (p = 0.02) following the 12 week study.

Another interesting angle to look at this from would be; is the increase in strength proportional to the increase in bone mineral density? Figure 9 shows at a glance each subject’s changes.
Figure 9: Increases in Bone and Strength Following the 12 Week Study

As seen in figure 9, there does not seem to be a proportional link between strength gains and bone gains. However, in order to fully substantiate this, a correlation test must be performed.

As shown in Appendix P normality was satisfied meaning that parametric tests can be used to assess the correlation between strength gains and increases in bone mineral density.

Appendix R shows there was no correlation between increases in strength and increases in bone mineral density following the 12 week study.
Section VII - Discussion

This study looked at the effect a 12 week strength training programme would have on the bone mineral density of postmenopausal women with 'low' bone density (t-scores below -1 on one or both legs). Women were chosen for this study as they are far more likely to develop osteoporosis than men (Powers & Howley, 2001; and Riggs, 1991). Furthermore, the women chosen were all postmenopausal and not taking hormone replacement therapy (HRT). The reason women on HRT were excluded was because HRT is literally a combination of oestrogen and progesterone (Nelson & Wernick, 2000). Oestrogen plays an important role in the response of bone to external loads (Bemben & Fetters, 2000) meaning that those taking HRT would stand a better chance of maintaining, or even improving, their bone mineral density during the 12 week strength training programme, than those not taking HRT. This would therefore skew the results of the study.

Many studies have looked at the effect of exercise coupled with another factor, for example calcium supplementation, HRT etc., on the effect of bone mineral density, however this is, to my knowledge, the first study to look at the effect on bone mineral density of single set strength training alone.

Bone

The word 'skeleton' comes from the Greek 'skeletos' meaning 'dried up' (Nelson & Wernick, 2000). However, this term must not be taken too literally as bone are very much alive (Nelson & Wernick, 1997). Bone is continually being remodelled (Plant & Tidey, 2003). Old bone is broken down by osteoclasts and new bone formed by osteoblasts (Vermeer et al, 2004; Ross & Denegar, 2001). It is the working ratio of the osteoblasts and osteoclasts that determines whether or not bones become brittle. The strength of the bone can adjust due to changes in stress placed on the bone (Plant & Tidey, 2003). For example, individuals who are regularly required to place heavy loads on their bones (be it for their job or other reasons) are usually found to have stronger thicker bones (Plant & Tidey, 2003). For this reason a prolonged strength training programme should also increase the bone strength of those who engage in it.

Before the 12 week exercise programme was undertaken the mean bone mineral density was marginally higher in the control group (91.83%, SD = 13.6) than in the
exercise group (85.19%, SD = 15.582), however, differences between the two groups were not deemed significant (p = 0.079).

At the end of the 12 week study final bone mineral density readings were taken and changes assessed.

**Control Group**
The control group members were randomly assigned and instructed to continue exercising in the same way they had been doing for the last 12 months. They were instructed not to make any changes to their exercise regime (be it activity, time, duration, intensity etc). They were also asked not to alter their diet and to refrain from starting to take calcium or vitamin D supplements during the 12 week study. Subjects who were already taking supplements and had been doing for the last 12 months were instructed to continue as normal.

The pre and post study bone density values were assessed using a paired t-test where there was found to be no overall significant difference between pre and post study values of bone mineral density (p = 0.485). To take this one step further the control group was then further spilt into left leg changes and right leg changes. Again a paired samples t-test was used to assess any changes. There were again no significant changes found in either the left leg (p = 0.859) or the right leg (p = 0.458) of the control group at the end of the 12 week study.

Therefore overall throughout the 12 week there was no significant change in bone mineral density of the 8 members of the control group.

**Exercise group**
The exercise group was also formed through random assignment. They too were asked to refrain from altering their diet or beginning to take any new supplements. Subjects were also asked to continue their exercise regime as normal with an additional five strength training exercises being performed three times each week.

In order to keep the study as accurate as possible the same set of tests were performed on the exercise groups' data. Firstly right and left leg values were combined and changes between pre and post study values were assessed. There was found to be a
significant difference ($p = 0.002$) between the initial results and the results following 12 weeks of strength training. As for the control group the results were split into left and right leg and assessed. Again there was found to be a significant difference in results for both the left leg ($p = 0.022$) and the right leg ($p = 0.046$).

Rhodes et al (2000) conducted a similar study looking at the effect of strength training over a 12 month period. Aside from the duration of the study, the major difference between this study and my study is that Rhodes et al (2000) used multiple set strength training as opposed to single set. Strength training, when done correctly, is very intense (Fleck & Kraemer, 1997). This study performed by Rhodes et al (2000), suggested that the subjects in the exercise group were participating in three hours of strength training per week, compared to my study which required a total of 60 minutes of strength training per week. Three hours of strength training may be deemed excessive for 65 to 75 year olds. Furthermore, excessive exercise (especially in a population not used to intense exercise) has been proven to cause microfractures in bones, which may negate the positive effects associated with ‘normal’ exercise (Plant & Tidey, 2003). In addition a study performed by Robling et al (2002) found that bone response to shorter bouts of loading (four bouts of 45 seconds, with each bout being followed by 3 hours of normal activity) was greater than bone response to longer bouts of loading (one bout of 180 seconds). Although this study used adult rats as the subjects Giangregorio & Blimkie (2002) state that rat models elicit similar biochemical reactions to unloading as humans. Like humans bone loss is also seen to be site specific. Furthermore, upon reloading the rat subjects were seen to increase bone mineral density (Giangregorio & Blimkie, 2002).

When load is exerted on bone via strength training (defined as 8 repetitions at 80% of 1RM), one set of 8 repetitions performed correctly should take around 48 seconds (working at a continual speed of 3 seconds lift and 3 seconds lowering with no rest in-between repetitions). Therefore, performing multiple sets on each muscle group may not have additional benefits. In fact, when a participant knows they have multiple sets to perform they are more likely to reduce the weight on their first set in order to be able to complete the following two sets. By doing this they are reducing the force applied to the bone in the first, and most crucial, 45 seconds. This may be one reason why Rhodes et al (2000) did not see any significant improvements in bone density following their 12 month study.
Ideally the 12 week study completed for this thesis would have insisted subjects engage in more than one training session per day would have been performed much like in the Robling et al (2002) study. However, due to time restrictions and other commitments it was not feasible for subjects to complete multiple sessions of the programme used for this study. Furthermore, Fleck & Kraemer (1997) state that more than one training session is not recommended for a newcomer to exercise. Whilst all the subjects involved in that study were regular exercisers, none of them used resistance training on a regular basis. Moreover none of the subjects were used to exercising at this intensity level (80% of their maximum).

Strength
As well as looking at changes in bone mineral density the study also looked at improvements in strength in the exercise group after the 12 weeks of strength training. Improving strength is important for numerous reasons. Firstly, muscles exert huge forces on the bone sites they are attached to (Glenville, 2005). As muscles become stronger (one way this can happen is through strength training), the forces they exert on the bones are increased (Nelson & Wernick, 2000). Therefore, the bones will respond accordingly (the more force exerted on them the more they will respond) (Glenville, 2005). By building stronger muscles bones will be stressed more (hence forced to develop) when performing activities of daily life (Nelson & Wernick, 2000).

Secondly improvements in strength have been linked to improvements in balance and co-ordination (Liu-Ambrose et al 2004; Ross & Denegar 2001; and Slattery 1996), therefore making it less likely a fall will occur in the first place.

One week following the initial bone density tests the subjects assigned to the exercise group underwent a series of strength tests using the 1 rep max formula (1RM). From the results of these strength tests a strength training programme was devised for each individual. The programme required the subjects to complete a series 5 resistance exercises three times each week. Theses exercises were specifically chosen as they work muscle groups that are attached to important areas of the skeleton. The chosen exercises were chest press, seated row, leg press, shoulder press and bicep curl. Each of these muscle groups are vital to everyday life and some, for example the seated
row, shoulder press and leg press, are attached to prominent skeletal points that are more prone to osteoporosis (for example the spine and the hip) (Nelson & Wernick, 2000).

During the study subjects were urged to keep increasing the weight they were lifting as they became easier. This was done to ensure they continued to work at a high intensity. Where possible meetings were held with the individuals every four weeks to re-assess their programmes. When this meeting was not possible a telephone conversation with the subject was used to assess their progress. In addition to this, should the subjects have encountered any difficulties or needed any help, there was always an exercise professional present in the gym when subjects were performing their exercises.

Following the 12 weeks of strength training the subjects repeated the strength tests to assess any differences. The same conditions, machines and formula were used. As seen in appendix N there proved to be a significant increase in strength following the 12 weeks of strength training.

However, it is still unclear whether or not this increase in strength and increase in bone mineral density are related. For this reason a correlation test was run on the data. This test highlighted that there was in fact no significant correlation between the increases seen in strength and the increases seen in bone mineral density.

Nevertheless, that does not mean to say both are not important. Remaining active, especially into old age, is very important for health (Nelson & Wernick, 2000). Becoming sedentary increases the likelihood of developing osteoporosis (Helge & Kanstrup, 2002 and Ross & Denegar, 2001). Furthermore age related strength losses are said to pave the way for bone loss (Bemben et al. 2000). In addition to the effect becoming sedentary has on bone mineral density, weight bearing activities such as resistance training carry with them other benefits such as improving strength, coordination and balance all of which will help reduce the likelihood of falling in the first place (Anonymous, 2004; Bemben & Fetters, 2000).
Section VIII – Conclusion

Traditionally old age is considered a time for reducing activity and accepting a decline in health (Evans & Meredith, 1989). In fact, even homes designed to care for the aged are termed “rest homes!” (Evans & Meredith, 1989). However, this is something that needs to change.

With prolonged life expectancy and the ever increasing elderly population, it is fair to say that, unless dramatic action is taken, osteoporosis related fractures will soon reach epidemic proportions. An increased awareness of osteoporosis, and the development of proven treatments is likely to increase the demand for more proactive primary care (Kanis et al. 2002).

The results of this study show that engaging in strength training on a regular basis (15 – 20 minutes three times a week); can have a positive effect on bone mineral density of post menopausal women with low bone density. Furthermore, all subjects involved in the exercise group reported other benefits such as feeling better and finding everyday tasks easier.

In addition, although the exercise was quite intense, nobody from the exercise group sustained any injury from the programme. Consequently, it may be in the interests of health care professional to promote strength training and physical activity to postmenopausal women. Aside from the effects on bone mineral density, there are numerous positive health benefits to be gained from engaging in regular exercise (Karvonen, 1996).

Although it is never too late to take action and improve health; and with that bone mineral density, the best way to prevent the onset of osteoporosis in later life is to achieve the highest possible bone mass at a young age. With this in mind, perhaps the most effective course of action would be to introduce preventative strategies to young people as part of their education.

In the mean time, all those who have bone mineral density T-scores of -1.5 or below should ensure they have a diet adequate in calcium, proteins and vitamins (especially important is vitamin D which can be made by the body from exposure to sunlight), they should also be reasonably active and take precautions to avoid falling.
Considering the magnitude of the problem, prevention is the only cost effective approach. Recommended daily intakes of dietary calcium should be achieved and increased physical activity should be encouraged. Bone toxins such as cigarette smoking and heavy alcohol consumption should be eliminated. Other controllable risk factors such as excessive consumption of protein and caffeine, along with a high salt intake should also be modified to more healthful levels. In addition measures should be taken to control and essentially lower high blood pressure. Incidentally, these measures (healthy diet and exercise) are also beneficial for bone health, making them doubly important.

A long-term plan, started at an early age, of moderate exercise combined with adequate calcium and vitamin D intake is the key to maintaining and improving bone health.
Section IX – Limitations

The CUBA McCue heel quantitative ultrasound scanner (or QUS) was used for numerous reasons:

1. It is a reliable indicator on bone mineral density and fracture risk
2. It is extremely portable
3. It is painless
4. It requires limited training to operate and interpret
5. Results are provided immediately
6. It is free from radiation

In spite of all this the best test available for determining bone mineral density is a Dual Energy X-Ray Absorptiometry (DXA or DEXA). Obtaining and using a DEXA scanner would be beyond the scope of this masters study.

For numerous reasons the number of subjects whom completed the 12 week study fell from 31 to 19. A larger sample size would have added more power to the findings.

In addition, subjects were left to their own devices for the duration of the study. The control group were asked to continue as normal for the 12 weeks and not engage in any new form of activity. The eight members of the control group who returned for the final bone mineral density test were asked if they had followed the instruction. Although they all insisted they had, there was no way to be entirely sure.

A similar limitation also arose for the exercise group. Although they were asked to keep an exercise log, there is no way to be sure the log was entirely honest. Subjects were all members of a country club where they visit for many reasons including swimming, tennis and even just to have lunch! No matter what activity they are engaging in, they are checked into the country club in the same way. So even though they may have visited the country club 6 times each week, they may not have completed the strength training programme once.

One way to eliminate this may have been to ensure that whenever the subjects (both exercise and control groups) visited the country club they were met by myself and monitored throughout their visit. Not only was this not feasible due to time restrictions of myself, it may have reduced the number of people willing to take part in the study.
As much as possible was done to ensure groups followed their instructions. The exercise group were asked to record each and every session in detail (date, number of repetitions and weights lifted). Subjects in the control group were quizzed about their activities over the 12 weeks. In fact three of the control group admitted to beginning the strength training programme after talking to some of the members of the exercise group. These subjects results were promptly excluded from the study!

As much as possible was done to control, or if not possible, estimate the effects of the confounding variables, although it has to be accepted that it was beyond the scope of this study to account for:

- Variability in perceived ‘ease’ of the exercise. Subjects were asked to increase the weight when it became ‘easier.’ This is a very individual measurement that can not be controlled.

- Truth of the subjects. Although all subjects insisted they followed their instructions it can not be guaranteed they were telling the truth.
Section X – Further Research

- A larger and longer study (12 months or more) of a similar nature, where subjects in the exercise group were supervised during each strength training session, may have ensured the subjects were always exercising at 80% of their 1RM.

- A study looking at three groups: Control, single set strength training and multiple set strength training, using DEXA to determine the effects of bone density change.

- Many people are unable to use a gym, and indeed participate in strength training, for health reasons. In fact some people even struggle to walk 100m. Because of this these people are at an increased risk of osteoporosis. However, many of these people can and, in some cases, are advised to use a swimming pool and even participate in aqua aerobics. Further research into the effects of different forms of aqua aerobics on bone mineral density in a population unable to exercise in conventional methods would be very useful.

- Similar to the study by Robling et al (2002), research into the effects of short bursts of high impact activity, for example skipping, hopping, jumping etc; on bone density of humans would be very useful.

- As suggested by Petranick & Berg (1997) more research into the threshold density needed to prevent fracture would be useful.

- Similar to this, research into the minimum amount of force needed to be place on a bone to promote adaptation.

- Research into the effect of educating people about osteoporosis. Does telling people about the dangers of osteoporosis and the positive effects of becoming active make a difference?
Section XI – Additional Information

Confidentiality
All information attained was strictly confidential and only available to myself (the researcher), the individual and my supervisor. Information stored on computer was protected by a password and any paper information was locked in a secure filing cabinet. Data was held as numerical codes only – no names were stored on the data files.

Experimental Design
The independent variable in this study was exercise or no exercise, and the dependent variable was bone mineral density.

In an attempt to control or estimate the confounding variables, a number of steps were taken. Subjects were asked:
- To keep an Exercise log
- To stick to the prescribed programme (just the exercise group)
- Not begin any new exercise classes or programmes
- Not to begin dieting

Pilot Study
The 1RM protocol was tested on members of the University of Chester Fitness Centre to ensure it was appropriate. Three members then complete four weeks of resistance training following the programme that will be used in the study.

Ethical Implications
After reading the Code of Practice Concerning Ethical Principles for Research, the following ethical implications applied to this study:

1. All the participants were fully informed about the study. They were required to read and sign an informed consent form containing a detailed account of the experimental design (appendix D). All subjects were free to withdraw from the study at any time.
2. Prior to the data collection the subjects were informed of their rights to privacy, non-participation, anonymity and confidentiality via a research summary and informed consent sheet.

3. Subjects were be identified by name. At no point did any person, other than the researcher, know the identity of any of the subjects. Subjects were dealt with by number only.

4. All information was dealt with solely by the researcher and was held in a secure computer file, the only other person who had access to the data was the research supervisor. All names were changed to numerical codes to protect identity.

5. Individuals kept their exercise logbooks for the duration of the time they were completing them.

6. Laboratory work was not needed for this study.
Section XII – Primary References


48


Section XIII - Secondary References

Appendices
Dear Donna,

Further to our telephone conversation on the 14th of this month, here are the details of the study I discussed with you.

Aim:

To assess the effect strength training has on the bone health of women with diminished bone density.

Method:

The study involves 4 stages:

1. Questionnaire distribution
2. First bone density assessment for those who meet the inclusion criteria
3. 12 week training programme set for those women whose bone density is within the set range
4. Final bone density assessment

For those members whose bone density falls into the set range, they will be offered the chance to take part in the 12 week study. The members will be assigned to one of two groups:

1. Exercise group
2. Control group

The exercise group will be given a weight-training programme specifically designed to increase their bone density. They will be asked to complete this 20 minute programme three times a week as well as continuing with their normal activities of daily life.

The control group will not be given an exercise programme. Instead they will be asked to continue as normal with their daily activities for the duration of the study.
At the end of the 16-week study both the exercise group and the control group will be given the second and final bone density scan.

All members who participate in the study will be given a pack containing information about how to look after their bones.

**Cost:**

The bone density scan will be free of charge to all members who meet the inclusion criteria. I will be using a portable heal ultrasound scanner for this.

I am very much looking forward to conducting this research! In addition to being a great opportunity for myself, I believe it will provide a valuable and interesting service for the members of Old Hall.

I look forward to speaking to you soon.

Yours Sincerely

Tracey Hunt Pg Dip, BSc (HONS)
FREE
Bone Density Scan
1 in 3 women and 1 in 12 men over the age of 50 in the UK will have osteoporosis

As part of my Masters Degree I will be offering free bone density scans to women over the age of 45.

If you would like to have your bone density checked please book in for an appointment at reception.

If you need any further information please do not hesitate to contact Tracey on 07976

Osteoporosis is a preventable and treatable disease
Appendix C

Inclusion and Exclusion Criteria

Inclusion Criteria: Not be involved in resistance training or high impact exercise during or postmenopausal
Female
Healthy
Have low bone mineral density (Low bone mineral density is defined as a T score of -1 SD (standard deviation) or below, when compared to "Normal."). This value is termed Osteopenia and is said to be the beginning of osteoporosis.

Exclusion criteria: Males
Actively involved in resistance training or high impact exercise
Injured
Normal bone mineral density
Recent hospital stay
Registered blindness
Severe hearing impairment
Uncontrolled hypertension or diabetes
Symptomatic cardiorespiratory disease
Severe renal or hepatic disease
Uncontrolled epilepsy
Progressive neurological disease
Chronic disabling arthritis
Anaemia
Marked obesity
Current use of beta-blockers
Oral anticoagulants
Central nervous system stimulants
Appendix D

Did you know osteoporosis is a preventable and treatable disease, yet more women die each year from osteoporosis related fractures than from breast cancer, uterine cancer and ovarian cancer combined.

Why have I been asked to participate in this study?

My name is Tracey Hunt, and I'm a Masters student at University of Chester – you may already know me as I am one fitness instructors who teaches classes here. Over the next three months I will be conducting a study for my Masters’ degree here at Old Hall Country Club. The aim of the study is to assess the effectiveness of a high weight, low repetition, training programme on bone mineral density. You’ve been asked to join the study following your heel ultrasound scan done on February. This sheet is for you to keep and will explain a little more about both the disease and the study that will be performed. The other sheet attached to this is for you to sign and return to myself should you wish to take part in the study.

What do I have to do?

If you choose to take part, you’ll be given two free bone density scans. This is a quick, non-invasive scan of your heel that will give you an idea of the health of your bones. If the results of the bone scan meet the inclusion criteria (below average bone mineral density for your age), for the study you will be invited to take part in the 3-month study. You will be placed into one of two groups: resistance training or control. If you are assigned to the resistance training group a 20 minute weight training programme will be specifically designed to suit you. You will need to complete the exercise programme three times each week. You will not need to be an experienced weight lifter – in fact the less you have used the gym the better! The programme will be updated at regular points throughout the 3-month duration of the study. If you are assigned to the control group, you will have to do nothing! Carry on with your normal activities as you were doing prior to the test. At the end of the study bone density will be tested again and advice given to everyone on the best ways to treat and prevent osteoporosis.
What is Osteoporosis?

Osteoporosis is defined as a reduction in bone mass and deterioration of bone tissue which leads to increased susceptibility to fractures. In other words bone tissue looses its mineral mass and becomes more porous and brittle. With aging bones can become hazardously fragile. Many people break bones resulting in pain, loss of independence and even death.

Ostertorotic fractures can occur from moderate trauma, such as a simple fall. In some cases bones become so fragile that every day activities such as lifting a baby out of a cot or even an enthusiastic hug may result in a break.

Osteoporosis is more common in women than in men. One in every three women and one in every twelve men in the United Kingdom will develop osteoporosis at some point during their life. In women, this is in part due to the lack of circulating essential hormones in the body during and following the menopause.

During the menopause bone loss is accelerated. This bone loss continues at a slower rate after the first 5 years of the menopause. Hormone replacement therapy (HRT) is thought to protect against loss of bone however many women do not take HRT as there are negative side effects associated with it.

However, there are alternatives to HRT. Regular habitual weight-bearing activity has been found to be beneficial for maintaining bone mass. It therefore seems plausible that applying a load greater than body weight (i.e. resistance training) will bring out an even more favourable effect on bone mineral density. This is the reason you are being asked to take part in this study.

Do I have to take part in this study?

Not at all! But if you do you will be a great help to me, and you may even find a new pastime you enjoy! However, you are free to withdraw from the study at any time....no questions asked!

Will anybody be told that I have taken part, or shown my results?

Your results will be kept absolutely confidential. Apart from you, the only person that will have access to them will myself, who is conducting the study. My dissertation supervisor will also know the results, but will not know your name or any aspect of your identity. The results of the study itself may be published, but your name or identity will not be revealed at any time.

If you would like to take part but are worried about confidentiality, feel free to fill in the form overleaf and give it to me in a sealed envelope. We can also arrange to do your bone density screening and exercise programme in another fitness centre if it would make you feel more comfortable.
Informed Consent Form
Strictly Private and Confidential

Yes! I'd like to do it!

I have read the above information, and at the moment, I'd like to take part in the study. I understand that I am freely able to withdraw my consent and participation at any time without any objection from the investigator. I am also aware that any personal information gathered by the researcher about me will remain strictly private and confidential.

Signature of participant

Name of Participant

Date

If you have any concerns or questions please do not hesitate to contact me on:
Physical Activity Readiness Questionnaire

Please answer all questions honestly. You will not be judged on any answers given. All questionnaire data will be stored in numbered computer files only accessible to the researcher. Your name or other information that may identify you will not be released to anyone without written consent.

If you have any questions or concerns about this questionnaire please do not hesitate to contact the researcher.

Personal Details
Name: ____________________________  Age: __________
D.O.B: ________________  Activity Level: ________________

Brief Medical History

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
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<tbody>
<tr>
<td>Do you have, or have you ever had any of the following?</td>
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<td>Bone/Joint problems?</td>
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<td>If yes please give brief details:</td>
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<td>Chronic dizziness?</td>
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<td>If yes please give brief details:</td>
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<td>Back injuries?</td>
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<td>Irregular heart rhythm?</td>
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<td>Chronic pain?</td>
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<td>If yes please give brief details:</td>
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<td>Epilepsy, seizures?</td>
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<tr>
<td>Chest pain?</td>
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<td>If yes please give brief details:</td>
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<td>Personal Medical History</td>
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<td>Are you currently taking any form of medication?</td>
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<td>Have you had to consult you doctor in the last 6 months?</td>
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<td>Respiratory Condition (asthma, emphysema, other)</td>
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<td>Cancer</td>
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<td>Musculoskeletal Conditions</td>
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<td>Heart Disease (angina, stroke, heart attack, other)</td>
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<td>Diabetes</td>
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<th>Cardiovascular Risk Factors</th>
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<td>Do you presently smoke cigarettes?</td>
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<td>If yes how many per day?</td>
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<td>Have you ever smoked in the past?</td>
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<td>If yes, when did you stop?</td>
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<td>Do you have a family history of cardiovascular health problems or other serious heart conditions?</td>
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<th>Please list all activities that you are currently involved in:</th>
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<td>Activity</td>
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Signed ___________________________________________ Date: 18-02-06
Extra Information

For the first couple of sessions the program will probably feel very hard and you may ache afterwards….this is NORMAL!

Whilst you are exercising you should feel some discomfort in the muscles (like a burning sensation) this is also normal. However, if you feel sharp or acute pain, (or have pain that does not go away afterwards) then STOP and call me before you try again!

As you get used to the programme the weights should start to feel easier! At this point try doing 9 or even 10 repetitions. When you are doing 10 repetitions and it feels easier then increase the weight (remember to use the 2.5 lever!) and go back to doing 8 repetitions again and so on!

Please write down the weight (W) and repetitions (R) you do on this program card in the appropriate boxes. This will make it easier for me when I do your next program, and also easier for you to remember what you did last time!

Other than that, try to enjoy it! I will call you at regular intervals anyway and you can call me if there is anything you want to discuss.

I will meet up with you again after your first 4 weeks and reassess your programme!

Many thanks again,

Tracey

---

Personal Fitness Programme

**Personal Details**

Name: A Pseudonym  
Programme No: 1  
Contact No:  
Date: 02-03-06  
Goals:  
   - Improve bone mineral density  
Time to work towards goals: 3 times per week  

---

**Attendance Record**

Please date the programme each time you complete it!

---

If you have any problems please do not hesitate to contact me on ??????????????.

There are some more instructions on the back too!

Good luck!
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<th>Chest Press</th>
<th>Upper Back</th>
<th>Leg Press</th>
<th>Shoulder Press</th>
<th>Bicep Curl</th>
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</tr>
<tr>
<td>W</td>
<td>30</td>
<td>35</td>
<td>90</td>
<td>8</td>
<td>9K</td>
</tr>
<tr>
<td>R</td>
<td>8</td>
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### Appendix G

#### One Way ANOVA

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<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig</th>
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<tbody>
<tr>
<td>Between Groups</td>
<td>683.878</td>
<td>1</td>
<td>683.878</td>
<td>3.183</td>
<td>0.076</td>
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<tr>
<td>Within Groups</td>
<td>12891.042</td>
<td>60</td>
<td>214.851</td>
<td></td>
<td></td>
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<tr>
<td>Total</td>
<td>13574.919</td>
<td>61</td>
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</tbody>
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Appendix H

Control Group: Tests of Normality

<table>
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<tr>
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<th>Kolmogorov-Smirnov(a)</th>
<th>Shapiro-Wilk</th>
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<td></td>
<td>Statistic</td>
<td>df</td>
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<tr>
<td>Control Group Bone</td>
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<td>Density (Right &amp; Left Combined)</td>
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</tr>
</tbody>
</table>

* This is a lower bound of the true significance.
  a Lilliefors Significance Correction

Exercise Group: Tests of Normality

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<th></th>
<th>Kolmogorov-Smirnov(a)</th>
<th>Shapiro-Wilk</th>
</tr>
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<td>df</td>
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<td>Exercise Group Bone</td>
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<tr>
<td>Density (Right &amp; Left Combined)</td>
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<td></td>
</tr>
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</table>

* This is a lower bound of the true significance.
  a Lilliefors Significance Correction
Appendix I

Pre Study Histograms for the Control and Exercise Group Bone Mineral Density

Histogram

Control Group Bone Density (Right & Left Combined)

Histogram

Exercise Group Bone Density (Right & Left Combined)
### Appendix J

#### Independent Samples Test

<table>
<thead>
<tr>
<th></th>
<th>Levene's Test for Equality of Variances</th>
<th>t-test for Equality of Means</th>
<th>95% Confidence Interval of the Difference</th>
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<tbody>
<tr>
<td></td>
<td>F</td>
<td>Sig.</td>
<td>t</td>
</tr>
<tr>
<td>Bone Density Left</td>
<td>.013</td>
<td>.911</td>
<td>1.266</td>
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<tr>
<td></td>
<td>Equal variances assumed</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Equal variances not assumed</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Equal variances assumed</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Equal variances not assumed</td>
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## Appendix K

### Paired Samples Statistics

<table>
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<th>Mean</th>
<th>N</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 1 pre</td>
<td>91.00</td>
<td>16</td>
<td>13.161</td>
<td>3.290</td>
</tr>
<tr>
<td>post</td>
<td>91.69</td>
<td>16</td>
<td>11.176</td>
<td>2.794</td>
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### Paired Samples Test

<table>
<thead>
<tr>
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<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>95% Confidence Interval of the Difference</th>
<th>Lower</th>
<th>Upper</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 1 pre - post</td>
<td>-0.688</td>
<td>3.842</td>
<td>0.961</td>
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### Appendix L

#### Paired Samples Statistics

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<th>N</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 1 postleft</td>
<td>90.00</td>
<td>8</td>
<td>9.621</td>
<td>3.402</td>
</tr>
<tr>
<td>Pair 2 preright</td>
<td>92.25</td>
<td>8</td>
<td>15.691</td>
<td>5.548</td>
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<tr>
<td>postright</td>
<td>93.38</td>
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<td>12.983</td>
<td>4.590</td>
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#### Paired Samples Test

<table>
<thead>
<tr>
<th>Paired Differences</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>95% Confidence Interval of the Difference</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 1 preleft - postleft</td>
<td>-0.250</td>
<td>3.845</td>
<td>1.359</td>
<td>-3.465, 2.965</td>
<td>-0.184</td>
<td>7</td>
<td>0.858</td>
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<tr>
<td>Pair 2 preright - postright</td>
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<td>4.051</td>
<td>1.432</td>
<td>-4.512, 2.262</td>
<td>-0.785</td>
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<td>0.458</td>
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### Paired Samples Statistics

<table>
<thead>
<tr>
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<th>N</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 1 pre</td>
<td>83.00</td>
<td>22</td>
<td>15.617</td>
<td>3.330</td>
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<tr>
<td>post</td>
<td>88.09</td>
<td>22</td>
<td>19.620</td>
<td>4.183</td>
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### Paired Samples Test

<table>
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<th>95% Confidence Interval of the Difference</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
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</thead>
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<td>Mean</td>
<td>Std. Deviation</td>
<td>Std. Error Mean</td>
<td>Lower</td>
<td>Upper</td>
</tr>
<tr>
<td>Pair 1 pre - post</td>
<td>-5.091</td>
<td>6.907</td>
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Appendix N

## Paired Samples Statistics

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<th>Mean</th>
<th>N</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
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</thead>
<tbody>
<tr>
<td>Pair 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>preleft</td>
<td>83.91</td>
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<td>16.434</td>
<td>4.955</td>
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<td>postleft</td>
<td>90.73</td>
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<td>22.059</td>
<td>6.651</td>
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<tr>
<td>Pair 2</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>preright</td>
<td>82.09</td>
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<td>15.501</td>
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<td>postright</td>
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<td>17.506</td>
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## Paired Samples Test

<table>
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<th>95% Confidence Interval of the Difference</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 1 preleft - postleft</td>
<td>-6.818</td>
<td>8.340</td>
<td>2.515</td>
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<td>Pair 2 preright - postright</td>
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Appendix O

Subject 1: Pre & Post Study Strength Test Scores (1 Rep Max)

Subject 2: Pre & Post Study Strength Test Scores 1 Rep Max
Subject 11: Pre & Post Study Strength Test Scores 1 Rep Max

![Graph showing weight lifted (as on machine) for different exercises: Chest Press, Seated Row, Leg Press, Shoulder Press, and Bicep Curl. The graph compares pre-study and post-study strength levels.](image-url)
Appendix P

Tests of Normality

<table>
<thead>
<tr>
<th></th>
<th>Kolmogorov-Smirnov(a)</th>
<th></th>
<th>Shapiro-Wilk</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Statistic</td>
<td>Df</td>
<td>Sig.</td>
<td>Statistic</td>
<td>Df</td>
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<td>STRENGTH</td>
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<td>.200(*)</td>
<td>.908</td>
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* This is a lower bound of the true significance.

a Lilliefors Significance Correction
### Appendix Q

#### Paired Samples Statistics

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<th>Pair</th>
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<th>Std. Error Mean</th>
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<td>Pair 1</td>
<td>Total Strength Pre Test</td>
<td>142.5455</td>
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<td></td>
<td>Total Strength Post Test</td>
<td>166.0909</td>
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<td>49.08707</td>
<td>14.80031</td>
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#### Paired Samples Test

<table>
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<tr>
<th>Paired Differences</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>95% Confidence Interval of the Difference</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
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<tr>
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<td>- Total Strength</td>
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<td>Post Test</td>
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xxvii
## Appendix R

### Correlation Between Strength and Bone Mineral Density Changes

<table>
<thead>
<tr>
<th></th>
<th>Strength increase in Kg</th>
<th>Bone density increase in %</th>
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<td><strong>Strength increase in Kg</strong></td>
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<td></td>
<td></td>
<td>11</td>
</tr>
<tr>
<td><strong>Bone density increase in %</strong></td>
<td>Pearson Correlation Sig. (2-tailed) N</td>
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<td></td>
<td>.427</td>
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