NUTRIENT INTAKE AND BONE DENSITY IN ACTIVE AND SEDENTARY POSTMENOPAUSAL FEMALES

by

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A thesis
presented to the University of Manitoba
in partial fulfillment of the
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INTRODUCTION

Increased longevity has resulted in a prevalance of old age diseases. One of the most widespread of these diseases is osteoporosis, or the involutional bone loss that occurs with advancing years in females. The decline in bone mass begins between the ages of thirty and thirty-five, and accelerates with menopause (Lukert, 1982; Gorrie, 1982; Cohn et al., 1976). As a result of this loss of bone mass an increased frequency of fractures is seen in this population (Krolner et al., 1982; Aloia et al., 1978; Brewer et al., 1983). American statistics indicate that one in four females over the age of forty-five will suffer compression fractures of the spine by age sixty, and one in two by age seventy. This phenomena is much more prevalant in females than in males. After the age of forty, females suffer from five times as many wrist fractures as males (Gorrie, 1982).

The causes of osteoporosis are largely speculative. Numerous studies have cited diet, inactivity, smoking, alcohol, height and weight as predisposing factors (Daniell, 1976; Saville & Nilsson, 1966; Lutz & Linkswiler, 1981).

Statement of the Problem

The purpose of this study was to determine the relationship between fitness level, bone density, dietary intake and hemoglobin level in postmenopausal females between the ages of forty-eight and sixty-five years. These variables were also compared in active and sedentary females of the same group.

Definition of Terms

Bone Mass. Refers to the absolute or total amount of bone present.

Bone Density. Refers to the thickness of the outer cortical layer of the bone and the density of the structural framework of the trabecula, or inner core, of the bone.

Postmenopause . As used in this paper, postmenopause refers to those females over 50 who have not experienced menses for the preceeding six months.

REVIEW OF RELATED LITERATURE

Introduction

Research has documented a decrease in aerobic power and physical work capacity, and an increase in body fat, with age in females (Drinkwater et al., 1975). Inactivity contributes to these changes as active, age matched females have greater aerobic fitness, and a lower percent body fat, than their sedentary counterparts.

Other parameters may be useful indicators of fitness level. Hemoglobin concentration may be related to health and fitness status as blood volume is known to increase with training, causing a decrease in hemoconcentration and a transient drop in hemoglobin (Mathews and Fox, 1981). Bone density has also been shown to decrease with age and inactivity in the human skeleton.

The following review closely examines skeletal health in postmenopausal females. Information concerning bone structure and loss, and factors affecting each is presented. Recent literature in the areas of physical activity and diet, and how they affect the skeletal health of postmenopausal females, is also included in this section.

Factors Affecting Bone Loss

Osteopenia is the term used to describe any pathological condition resulting in a reduced bone mass. In osteoporosis, a form of osteopenia, there is a loss of cells from the structural core of the bone, the trabecula. Cortical thinning, or a reduction of growth on the outside surface of the bone, also occurs, as a result of increased resorption or a decreased deposition of bone (Lane & Vigorita, 1983).

Riggs et al., (1981) reported that the loss of bone mineral differs in specific areas of the body depending on the proportion of trabecular to cortical bone. Two areas most often used as indices in the diagnosis of osteoporosis are the distal radius and the vertebrae. The radius is predominantly cortical bone, and the vertebrae largely trabecular (Riggs et al., 1981). A linear decrease in trabecular bone mass was also noted, with increasing age in females, although this loss was somewhat accelerated after menopause. In the areas where cortical bone predominated there appeared to be a sharp decline in bone mass upon reaching menopause, suggesting that cortical areas are more sensitive to estrogen deficiency than trabecular bone.

Over the course of a lifetime it is estimated that females lose 45% of vertebral bone mass and 39% of the distal radial bone mass (Riggs et al., 1981; Mattson, 1984). The remaining bone, however, is chemically normal and the miner-

al content is unchanged, although it is porous and brittle (Gorrie, 1982).

There are three phases of skeletal health in humans. During growth there is an increased deposition of bone leading to an increase in the mass and density of the skeletal structure. In the early adult years, growth ceases and bone deposition equals bone resorption. By approximately thirty years of age, bone resorption is greater than bone deposition, resulting in more porous bones (Cohn et al., 1976). The bone loss progresses very gradually until the fifth decade when there occurs a drastic reduction in estrogen followed by a two-fold increase in the rate of bone resorption (Kleerekoper et al., 1981).

The mechanism by which estrogen loss results in bone loss is still speculative. Although estrogen receptors have not been found in bone cells, it is theorized that estrogens indirectly inhibit bone resorption (Kleerekoper et al., 1981). Heaney et al., (1978) proposed one possible mechanism whereby there is an estrogen stimulated decrease in parathyroid hormone (PTH) and increase in 1,25 dihydroxycholicalciferol (1,25 DHC) levels. It is known that PTH stimulates bone resorption and 1,25 DHC is the active form of Vitamin D necessary for calcium absorption. These hormones are intimately related in that a decrease in estrogen, causes an increase in PTH which in turn inhibits the activity of 1α-hydroxylase. This is the enzyme responsible for the conversion of

inactive 25 hydroxycholicalciferol (25 HC) to the metabolically active 1,25 DHC (Lore et al., 1984; Lukert, 1982; Chestnut, 1981). Conversely, it was found that when estrogens were administered to estrogen deficient females, aside from favourably reversing the PTH and 1,25 DHC effects, there occurred an improvement in the gastro-intestinal absorption of calcium and a decrease in the urinary excretion of calcium (Lukert, 1982).

Another hormonal change occurring with menopause is a reduction in plasma levels of growth hormone. Since growth hormone is known to increase bone deposition, decreased levels will favour a further relative increase in bone resorption (Oyster et al., 1984).

Bone loss is at its peak in early postmenopausal years and the rate of loss diminishes in later years (Smith et al., 1976). However, the rate of loss is related to the initial bone mass. Individuals with a high bone mass will have a much greater initial bone loss than those individuals with a lower bone mass.

There are a number of other factors which have been found to be instrumental in the development of osteoporosis. Daniell (1976) suggested that cigarette smoking will predispose one to bone loss. Smoking has been associated with early menopause which could advance the osteoporotic process (Aloia et al., 1985; Peck, 1984). Other smoking related chang-

es adversely related to bone loss are blood pH changes causing increased parathyroid activity, presence of respiratory disease linked to osteoporosis, and lowered blood oxygen tensions at sites of oxygen consumption (Daniell, 1976).

Chalmers and Ho (1976) recognized that racial variations existed in osteoporosis. It was noted that African and American blacks have much denser bone than do Caucasians. This difference in bone density does not seem to be related to dietary factors as blacks consume low levels of calcium, relative to Caucasian counterparts (Chalmers & Ho, 1970).

Body size has also been found to influence the incidence of osteoporosis. Saville and Nilsson (1966) found that osteoporotic females were significantly shorter and lighter than non-osteoporotics.

Physical Activity and Bone Loss

The extent to which bone loss can be inhibited is a controversial issue. Exercise, the panacea of the eighties, has been given extensive consideration with regard to the prevention of bone loss in postmenopausal females. Khairi and Johnston (1978) noted the possibility of bone loss in elderly females as being a by-product of decreased activity of daily living, rather than one of advancing age. However, Oyster et al., (1984) suggested that although aging and inactivity are associated with bone loss, it is unknown wheth-

er the same mechanism causes bone demineralization in each case.

It is well documented that immobilization, weightlessness or impaired muscle function result in bone loss in human subjects. Donaldson et al., (1970) demonstrated this phenomena in a thirty-six week bed rest study involving three young men who lost 39% of their bone mineral after immobilization. Smith (1982) pointed out that bone loss is a result of a reduction of either muscular contraction or the pull of gravity. Conversely, an increase in these two mechanical forces will result in bone hypertrophy. Nillson and Westlin (1971) measured the bone densities of femurs in sixty-four athletes using a photon-absorption method and compared them to thirty-nine healthy controls of the same age distribution. The athletes were found to have significantly greater femoral bone density than their non-athletic counterparts.

Jones et al., (1977) looked at the asymmetric bone densities of the humeri of tennis players. The playing arms and the non-dominant arms of eighty-four active tennis players were measured roentgenogramically and compared for differences. Each tennis player demonstrated a substantial hypertrophy of the playing arm with a difference of 34.9% for men and 28.4% for women.

The mechanical laws which govern bone equilibrium were first examined by Wolff in 1870. Wolff's law of bone equi-

librium states "when a bone is bent under a mechanical load, it modifies its structure by bony apposition in the concavity and by resorption in the convexity" (Chamay & Tschantz, 1972). Bone reacts to forces causing elastic deformation by a slow remodelling process in the direction of the axis of the force. This property of bone has been referred to as peizoelectricity. Bassett (1968) describes peizoelectricity as electricity resulting from pressure on polycrystalline materials, such as bone. When these materials are deformed, the crystalline substance experiences charges of opposite polarity on opposite faces of the crystal. In other words, when bone tissue is stressed a negative charge is produced by the compressed segment and a positive charge produced by the extended segment (Smith, 1982). This results in a build-up of calcium ions around the negative pole and calcium removal from the positive pole. In order for this peizoelectrical phenomena to occur, the anti-gravity muscles have to be employed (Falch, 1982). For this reason, exercise carried out by bed ridden or wheelchair patients is not as effective in reducing bone loss as exercise performed in an upright position.

Issekutz et al., (1966) conducted a calcium balance study using healthy, young, immobilized males. These individuals were in negative calcium balance as indicated by an increase in urinary calcium. This caused a decrease in serum calcium which was then corrected by a resorption of calcium from the

bone. The calcium balance did not return with bed exercise but calcium excretion did decrease when the subject was mobilized in a standing position for three hours a day.

Although this data indicates that a certain amount of weight bearing activity promotes an increase in bone mass, the extent of activity necessary to prevent bone loss or actually increase bone density is not clear. Dalen and Olsson (1974) conducted a study to investigate the bone density of active and inactive individuals. One group was composed of fifteen male cross-country runners aged fifty to fifty-nine, who had been training for at least 25 years. The second group was designated the short term, physical activity group, and was composed of nineteen males aged twenty-five to fifty-two. This group trained for three months. Ten individuals from this group walked 3 km, five times per week, and nine persons ran 5 km, three times per week. A random sample of thirty-one males from the Stockholm population was designated as the control group. These controls were of similar body size, height, and weight as the cross country runners. Bone mineral content of the three groups was determined by X-ray spectrophotometry. The sites measured were the shaft of the radius, ulna and femur, distal radius and ulna, femoral neck, humeral head, third lumbar vertebrae and the calcaneous. Results indicated that the bone mineral content was 20% greater for the runners in the appendicular skeleton, but only 8 to 9% greater in the axial skeleton as

compared to the control group. Although both three month training groups experienced an increase in maximal oxygen uptake, there appeared to be no significant increase in bone mineral content in any site measured. This suggests that individuals must participate in a long term physical activity regimen before significant increases in bone mineral content are to be realized.

Animal models have also been used to examine the physical activity related increase or decrease in bone density. Saville and Whyte (1969) studied exercise effects on the bone densities of thirty-five rats as compared to sedentary controls. The active group was made to run 2000 metres a day, five days a week, and then humanely killed. The exercise group experienced an increase in bone of normal density. There was also a greater amount of bone calcium in the exercise group than in the control group at any body weight. The amount of calcium relative to bone volume remained unchanged. This effect is transient as demonstrated by the finding of Le Blanc et al., (1983), in that the bone calcium gain achieved through exercise is lost following the cessation of exercise.

Although physical activity has been determined to be beneficial in promoting skeletal health, females have the superimposed stress of estrogen loss. Therefore, regular activity is extremely important in this group in order to offset the negative effects that estrogen loss has on bone health.

Although some bone loss is an inevitable part of the aging process, especially in females, the research suggests that with an active healthy lifestyle the degree of loss can be modified. Brewer et al., (1983) illustrated differences in bone density in females with different activity habits. The purpose of the study was to determine whether active females maintained bone mineral content longer than inactive females throughout the middle-aged years. Forty-two active females aged thirty to forty-nine were studied. These females had been training for two years and were currently involved in marathon training, averaging forty miles per week. The age matched control group consisted of thirty-eight females who had not participated regularly in exercise for two years. All women were white and premenopausal. Bone mineral status in the non-dominant hand and left foot was determined by X-ray densitometry and single photon absorptiometry. Several anthropometric measures including height, weight, skinfold thickness, girth and body dimensions were obtained. Results indicated that sedentary females were significantly heavier, had larger skinfold measures and greater body dimensions than the active group. Bone measurements indicated that there was a loss of bone with age in the sedentary group, whereas the runners had either increased or stable bone mineral content with age. This supports the previously mentioned theory that physical activity is a major factor in influencing bone mass.

It has been noted that when menopause is reached there is a sharp increase in bone loss associated with the loss of estrogen. Oyster et al., (1984) attempted to determine whether an optimal level of exercise during this time could offset or act as a retardant of bone loss. Two groups of females aged sixty to sixty-nine were studied. One group consisted of subjects who had been physically active throughout their lives, while the second group had led a more sedentary lifestyle. Group distinction was made via a physical activity profile which recorded data relating to activities of daily living, recreational pursuits and planned fitness pursuits over a three day period. A nutrient profile was also obtained to be certain no abnormal intakes of calcium, Vitamin D and flourine existed. Comparison of the second metacarpal of the non-dominant hand was carried out by X-ray and was measured to determine if differences existed between the active and sedentary groups. Height, weight, ponderal index and hormone therapy were also measured. Results indicated that the active females had a greater cortical diameter and therefore, a greater bone mass than the inactive group. A positive linear relationship existed between the length of time the subject had regularly participated in exercise and the cortical diameter. Also, the subjects with the smallest cortical diameters were significantly lighter than the subjects with the largest cortical diameters. Even within the inactive group, the heavier females had a greater cortical diameter.

Smith et al., (1981) conducted a study where an exercise program was actually introduced and administered to a group of normal elderly (69 - 95 years) females from a nursing home over a three year period. The physical activity program consisted of light to mild activities (1.5 to 3 METS) such as leg walks, leg spreads and side bends from a chair. The frequency of the program was thirty minutes per day for three days a week. This group was compared to an inactive control group and matched for age, weight and degree of ambulation. In both groups, the bone mineral content and width of the radius was measured at two sites via photon absorptiometry. The results indicated a significant increase in bone mineral content in the physically active as compared to the control group after the three year test period.

In the normal pre and postmenopausal female, bone loss can be retarded with exercise. Females with clinically diagnosed osteoporosis, however, are difficult to treat with exercise because even a minimal amount of mechanical stress can lead to fracture (Yeater & Martin, 1984). It is apparent that exercise is a preventative tool for osteoporosis rather than a rehabilitative tool.

Even though physical activity is respected as a rehabilitative and preventive tool, there seems to be a point where exercise becomes dysfunctional. Gonzalez (1982) looked at the phenomena of premature bone loss in non-menstruating female athletes. Eighteen non-menstruating female runners (19

to 49 years) suffered from hypothalamic (hyperprolactinemia) amenorrhea and very low body fat. It was found that the group had a mean of 28% less bone mass than 45 age matched control subjects. Amenorrheic females with low body fat levels are known to have low levels of estrogen because subcutaneous fat is the site for aromatization of the adrenal hormone, androstenedione, to estrogen (Linnell et al., 1984). In an attempt to relate activity level to amenorrhea and bone loss, Drinkwater et al., (1984) examined two groups of female athletes matched for age, height, weight, sport and training regimens. The dietary intakes of the two groups were found to be similar. The amenorrheic group ran an average of 67.3 km per week, significantly greater than the eumenorrheic group, who ran 40.3 km per week. No differences were found between groups for bone mineral or density of the radius. When vertebral mineral densities were compared the eumenorrheic group had values close to age predicted values, however, the amenorrheic group had a lower average mineral density. In fact the values of the amenorrheic group were equivalent to that of a fifty-one year old, and two of the athletes in this group actually had mineral densities below the fracture threshold.

Diet and Bone Loss

Diet plays an integral role in skeletal health. Several nutrients are strategically involved in bone health, especially calcium, phosphorus, Vitamin D, fluoride and protein. Numerous dietary surveys have been carried out to assess the dietary habits of older adults.

Twenty-four hour recalls have been found to be a valid instrument in assessing dietary differences between groups (O'Hanlon & Kohrs, 1978). In subjects over the age of fifty-nine, caloric intake has frequently been reported as inadequate as has calcium intake, especially in females (O'-Hanlon & Kohrs, 1978). Protein is generally adequate in this group of individuals.

Calcium and Phosphorus

Skeletal tissue contains 99% of the body's calcium and 80% of the body's phosphorus. The hydroxyapatite crystals of the bone are composed of a 2:1 ratio of calcium to phosphorus (Ca:P). It is difficult, however, to achieve this ratio in our diets due to three factors: the relatively low availability of calcium in foods, whereas phosphorus is ubiquitous in the food supply; foods high in calcium are generally rich in phosphorus as well; and the high amounts of phosphorus in food additives, and in commonly consumed foods such as meat, eggs, potatoes and bread make it difficult to limit phosphorus intake.

The Canadian Dietary Standard (Health and Welfare Canada, 1983) recommends a calcium intake of 800 mg per day for older Canadians (over fifty years of age). Some researchers, however, have suggested that the daily requirement of calcium should be 1 gram per day for the average person and 1.4 grams per day for postmenopausal females (Heaney, 1977). Jowsey (1976) recommended a calcium supplement for all females over twenty-five because calcium intake decreases at approximately age twenty and bone loss begins as early as thirty years of age in the average sedentary individual.

The influence of dietary calcium on age related bone loss in humans is controversial. While African and American blacks have virtually no incidence of osteoporosis while consuming minimal calcium, the Canadian Eskimo, with a marginal intake of calcium and Vitamin D, experiences from 10% to 15% bone loss per decade after 40 years. However, this population also consumes an extremely high protein diet, and experiences minimal sunlight, both of which have been implicated in bone loss (Mazess & Mather, 1975).

Matkovic et al., (1979) studied the effects of differing calcium intakes on skeletal health by examining the fracture rates of individuals in two regions of Yugoslavia where different levels of calcium were consumed. It was found that females who consumed an average of 812 mg per day of calcium suffered from less bone fractures than those who consumed 500 mg of calcium.

Calcium absorption is affected by several factors including dietary calcium, phosphorus, Vitamin D and protein intake (Jowsey, 1976). Plasma calcium homeostasis is thought to be maintained regardless of dietary calcium intake. This homeostasis is thought to involve a feedback mechanism which regulates the amount of calcium absorbed and excreted. Phosphorus has no comparable mechanism in the body (Draper & Scythes, 1981). It is also known that aging decreases the amount of calcium absorbed and the ability to adapt to changes in calcium intake. Therefore, as an individual ages, the Ca:P ratio will gradually change to favour phosphorus even if the diet remains relatively unchanged. As mentioned previously, the optimal Ca:P ratio in the diet is 2:1 as this is the ratio found in the bone matrix. Studies have shown that actual decreases in bone mass were observed only at Ca:P ratios of 1:2 and 1:3. This decrease in bone mass due to an excess of dietary phosphorus is a common occurrence in the Western diet. Excess dietary phosphorus results in an increase in plasma phosphorus, a decline in plasma calcium, an increase in PTH synthesis and a consequent increase in bone resorption (Draper & Scythes, 1981).

The absolute phosphorus and calcium intakes must also be considered. For example, rat studies have shown that when calcium intake is low (0.3% of the diet) no effect on bone mass is noted when phosphorus is ingested at a ratio of 1:2. When calcium is raised to a concentration of 0.6%, a ratio

of 1:2 will cause a loss in bone mass. At a high calcium intake of 1.2%, a 1:1 ratio adversely affects bone mass. At a very high concentration of calcium (2.4%), a decreased bone mass is seen at Ca:P ratios of 2:1 (Draper & Scythes, 1981; Bell et al., 1980). This phenomena can be explained by the nature of calcium absorption. As well as decreasing with age, calcium absorption decreases with increasingly higher intakes, whereas the phosphorus absorption efficiency remains the same.

Several researchers have investigated the effects of high phosphorus diets on bone homeostasis. Bell et al., (1977) studied the physiological effects of a normal diet, with and without phosphate food additives, on human subjects aged twenty-four to thirty-six. During the low phosphate treatment, subjects consumed 677 mg of calcium per day and 979 mg of phosphorus. During the high phosphate treatment, subjects consumed 745 mg of calcium and 2124 mg of phosphorus per day. It was found that the high phosphate group experienced significant decreases in serum and urinary calcium and increases in serum and urinary phosphorus, as well as intestinal distress and mild diarrhea. Bell et al., (1977) concluded that diets high in phosphorus are associated with an increase in PTH causing an increase in calcium mobilization from the bone. This in turn leads to a subsequent loss of calcium in the feces. Bauer and Griminger (1983) further commented on this mechanism stating that phosphorus actually

complexes with calcium resulting in a reduction in serum ionized calcium and eventually, bone resorption.

LaFlamme and Jowsey (1972) studied high phosphorus diets in dogs. Of main interest were the effects of this diet on PTH secretion, bone turnover and calcium retention in soft tissue. An oral phosphate supplement was given to ten dogs over a ten month period. This supplemention caused an increase in bone resorption without a parallel increase in bone formation. The bone appeared to be more porous than before the supplementation period. There was an increaase in PTH levels and these were positively correlated with the decrease in bone mineral content. There was also an increase in calcium in several soft tissues of the body, mainly the kidney.

Given these detrimental effects of excess phosphorus in normal adults and dogs, it is of interest to investigate the effects in postmenopausal osteoporotic females. Goldsmith et al., (1976) selected seven postmenopausal females between the ages of sixty- three and seventy-five, all suffering from osteoporosis. A diet history was obtained and diets prepared for each individual to ensure the intake of calcium and phosphorus remained constant. Each subject received a phosphorus supplement of 1 gram per day for fifteen months. To assess skeletal health, a bone biopsy was taken from the iliac crest to determine formation and resorption surfaces. Bone density was assessed via bone densitometry of the dis-

tal and mid shaft radius. The results indicated, as noted previously, a decrease in urinary calcium and an increase in fecal calcium. The bone biopsy revealed a decrease in the bone formation surface and an increase in the bone resorption surface, resulting in a net loss of bone. One surprising outcome was a lack of significant change in serum PTH levels.

Vitamin D

The status of Vitamin D intake in North America is generally good, due to the enrichment of common foods and frequent exposure to sunlight. However, deficiencies may occur, especially in the elderly who often have limited sun exposure and consume inadequate amounts of Vitamin D. Liver or kidney disease may cause a functional Vitamin D deficiency because these are sites where Vitamin D is metabolized to the active metabolite 1,25 DHC. Gastrectomies or malabsorptive diseases may also result in Vitamin D deficiency because it is a fat soluble nutrient and is lost in the feces if absorptive problems are present (Jowsey, 1976). The active form of Vitamin D is one of the major calcium regulating hormones. Recent data suggests that osteoporotic females have lower 1,25 DHC plasma levels than normal age matched controls (Lore et al., 1984). Olson (1983) suggested that this low level of active Vitamin D is a result of age related decreases in renal function. This results in a

deficient renal synthesis of active Vitamin D leading to a malabsorption of calcium. This reduced serum calcium leads to an increase in PTH in an attempt to enhance the renal secretion of 1,25 DHC.

Heaney et al., (1978) suggested another mechanism to explain low levels of 1,25 DHC in osteoporotic females. As a result of inactivity, estrogen deficiency, or age, there is an imbalance between bone formation and bone resorption resulting in a net bone loss. This causes the PTH levels to decrease due to more calcium being released than taken up by the skeleton. This increased level of calcium in the blood results in a further decrease in 1,25 DHC levels in the blood,a decreased efficiency of intestinal calcium absorption, and reduced renal calcium retention ability. Ultimately, low levels of 1,25 DHC have a negative effect on skeletal health.

Lore et al., (1984) also looked at levels of Vitamin D metabolites in postmenopausal osteoporotic females. Twelve subjects, aged fifty-two to seventy-four years of age were studied. The dietary intakes of calcium and Vitamin D were 1 g and 1 ug, respectively. The recommended dietary intake of Vitamin D in females fifty and over is 2.5 ug per day. The serum levels of the three main Vitamin D metabolites; 1,25 DHC, 25 HC and 24,25 DHC, were measured and compared with levels in age matched normal controls. It was found that the osteoporotic group had higher levels of both inac-

tive metabolites, 25 HC and 24,25 DHC, however, the levels of the active metabolite, 1,25 DH, were significantly lower. The decreased levels of 1,25 DHC in the osteoporotic group could be a result of inadequate levels of 1^{α} -hydroxylase (1^{α} -H). Gallagher et al., (1979) also found levels of 1,25 DHC to be lower in osteoporotic females. A flow chart illustrating the preceeding interrelationships is found in Figure 1.

↓ESTROGEN > ↑CALCIUM RESORPTION FROM BONE > ↑SERUM CALCIUM > ↓PTH > ↓ 1^{α}-H > ↓1,25 DHC > ↓INTESTINAL CALCIUM ABSORPTION

Figure 1: Metabolic factors affecting calcium absorption

When considering dietary management of osteoporosis, however, it has been found that the administration of Vitamin D metabolites is not useful and may actually be harmful because of the toxic nature of this fat soluble vitamin. Nordin et al., (1980) recommended that they only be prescribed in conjunction with estrogens, which enhance the conversion to the active Vitamin D metabolite.

Protein

Dietary protein may also influence skeletal health. There is much controversy as to whether a high protein diet, as is commonly consumed in Western society, causes an increase in urinary calcium. Spencer et al, (1978) administered two levels of protein to males consuming varying levels of calcium. The protein levels given were 2g/kg and 1g/kg to individuals consuming 200, 800, 1100 and 2000 mg of calcium per day. The urinary calcium did not significantly change at any level of protein or calcium intake. These researchers hypothesized that the absence of urinary calcium increase was due to increased levels of phosphorus found in the high protein (meat) diet.

Bell et al., (1975) also looked at the effect of varying levels of dietary protein on calcium metabolism. Rats were fed different amounts of protein (10, 20 and 40% of diet) with calcium and phosphorus intakes held constant. It was found that with increasing levels of protein, urinary calcium increased and fecal calcium decreased. However, when the rats were fed a high phosphorus diet (1.2%) an increase in calcium loss of about 50% was noted. It was speculated that the increase in calcium absorption resulting from the increased protein could not offset the bone resorption caused by high phosphorus intakes. These authors concluded that a high protein diet had no effect on bone resorption when calcium and phosphorus intakes were adequate. These results

are not in agreement with Linkswiler et al., (1981) who compiled a comprehensive review on protein induced calciuria. These researchers believe the mechanism involved in the calciuria observed in various studies is related to a protein induced alteration in kidney function. The glomerular filtration rate (GFR) has been found to increase by 10% to 15% when protein intake is raised two to three times, causing an increase in calcium in the urine. A decrease in renal tubular resorption of calcium (FTR Ca) has also been reported when protein intake is increased, again resulting in calciuria.

Although there is conflicting data concerning the effects of protein on calcium balance, the protein intake of the elderly has generally been found to be adequate. Perhaps it is the source or type of protein consumed rather than the level of protein that is the crucial factor. Whiting and Draper (1980) examined the effects of different sources of protein on calciuria in rats. The proteins given were lactalbumin, egg white, casein and gelatin. The extent of hypercalciuria was found to be directly related to the total sulfur amino acid content of each protein. Lactalbumin, the highest in sulfur amino acids (a.a.) produced the greatest rise in urinary calcium. This calciuria was highest two days after the initial protein feeding and gradually decreased to a stable moderate hypercalciuria after four weeks. Egg whites produced the next highest calciuria, and

gelatin produced the smallest urinary increase in calcium. It is thought that sulfate ions from the high sulfur amino acid proteins complex with calcium ions in the renal tubular fluid and prevent calcium absorption.

Lutz and Linkswiler (1981) studied the effects of sulfur amino acids on calcium metabolism in postmenopausal females. High protein-high sulfur a.a. and low protein-low sulfur a.a. were administered to two groups. One group consisted of four osteoporotic females and the second group consisted of four normal controls. The effects of these diets on calcium absorption, urinary calcium, calcium balance, serum PTH, plasma 1,25 DHC and plasma calcium were examined and group comparisons were made. Each group consumed a high protein diet and a low protein diet for fifteen days. The high protein diet contained 110 g of protein of which lactalbumin made up 31 g and wheat gluten made up 51 g. This increased the sulfur amino acid content of the high protein diet by 3.2 g per day. The calcium and phosphorus contents of the diets were 713 mg and 1078 mg respectively. The results are interesting in that there were no differences between the osteoporotic and non-osteoporotic groups for urinary and fecal calcium, serum PTH, plasma 1,25 DHC and plasma calcium. The two groups as a whole demonstrated a significant increase in urinary calcium and a decrease in fecal calcium with the increased protein intake. This illustrates that excess dietary protein with high levels of

sulfur amino acids has a calciuretic effect on the kidneys and also causes increased intestinal absorption of calcium.

Licata et al., (1981) conducted a similar study using varying levels of sulfur amino acids in the diets of five osteoporotic females. The high sulfur, high protein diets caused significant increases in urinary phosphate and calcium. Also noted was an increase in urinary acidity and nitrogen. Unlike the previous study, there was little change in fecal calcium resulting in a negative calcium balance. Although bone measurements were not taken, the authors concluded that the negative calcium balance induced by high sulfur amino acids containing protein may lead to bone loss.

Interrelationships between nutrients also have to be considered in skeletal health. A diet high in both sulfur amino acids and phosphorus, in addition to the decreased estrogen occurring in menopause, could result in a predisposition to bone disease.

The maintenance of bone tissue is a multifactorial process. Numerous variables have to be considered in order to procure optimal skeletal health. A moderate lifetime level of physical activity maintained into the postmenopausal years is identified as an important factor. The consumption of optimal levels of the key nutrients identified in this review would also assist in reducing the fracture risk in this population.

METHODS AND PROCEDURES

Introduction

The purpose of this study was to determine the relationship between fitness level, bone density, dietary intake and hemoglobin level in postmenopausal females between the ages of forty-eight and sixty-five years of age. These variables were also compared in active and sedentary females of the same group.

Subjects

Twenty-eight postmenopausal females between the ages of forty-eight and sixty-five years were selected to take part in the study. Active subjects (N=11) were determined by contacting various sport associations and by "word of mouth". Sedentary subjects (N=17) were selected from respondants to newspaper ads, posters and via "word of mouth". Members of both groups had to meet the following criteria:

1. reside in a flouridated area
2. Caucasian
3. free from hormone therapy for the previous five years

In addition, active subjects had to meet the following criteria:

1. maximum oxygen uptake of 35 ml/kg /min or greater
2. actively training for the past three years (three times per week for at least 15 minutes), as established by the questionnaire in Appendix A.

Sedentary subjects had to meet the following criteria:

1. maximum oxygen uptake of less than 35 ml/kg /min
2. have not actively trained in the past three years (as established by the questionnaire in Appendix A)

Subjects were informed of all risks and discomforts that might arise as a result of the various tests and signed a consent form (Appendix B).

Data Collection

Exercise Data

Predicted Maximal Oxygen Uptake.

A twelve minute, three stage, incremental, submaximal test was administered to each subject. A cycle ergometer (Monark, Sweden) was used and workload increments were imposed every four minutes. Heart rate was recorded from a bipolar chest lead (V5) using an electrocardiogram (Cambridge,New York). The steady state heart rate at the eleventh and twelfth minute was used to determine maximal oxygen uptake using the nomogram developed by Astrand (1960).

Anthropometric Measurements.

Skinfold calipers (John Bull, England) were used to obtain measurements from specific sites on the triceps, biceps, subscapularis and suprailiac. The sum of skinfolds was determined from these measurements and compared to norms found in the Standardized Test of Fitness (Fitness and Amateur Sport, 1985). Percent body fat was also predicted using the equation of Durnin and Womersley (1974).

Height was measured from the highest point on the head to the nearest 0.1 cm using a stadiometer (Harpenden, England). Weight was measured with minimal clothing and without shoes, to the nearest 0.1 kg using the Healthometer (Continental Scale Corporation, Illinois). Protocols for both height and weight were taken from the Canadian Standardized Test of Fitness (Fitness and Amateur Sport, 1981).

Peak Torque.

Peak torque was measured during knee extension and flexion, using the Cybex II Isokinetic Dynamometer (Lumex, New York). Each subject was seated with a 90 angle at the hip joint, and a belt secured across the leg being tested. The rotational axis of the resistance arm and pivot point of the knee were aligned. The Cybex II recorder was set at a damp setting of 2. Subjects performed 3 warm-up contractions at approximately 50% effort and 1 at 100% effort. Following a 2 minute rest the subjects were encouraged to perform 4 max-

imal contractions at a velocity of $60^{o}/s$. The knee was in full flexion at the start of each measurement, and was then fully extended to 0^{o}.

Grip Strength.

Each subject was asked to perform a strength test using a grip dynamometer (Takei Kiki Kogyo, Japan). The non-dominant hand was tested and the best score (kg) of two trials was recorded.

Bone Density Data

Each subject reported to the Respiratory Rehabilitative Hospital at the Health Science Complex, where an X-ray was taken of the second metacarpal of the non-dominant hand in the P/A and oblique position. Single emulsion extremity film was used at an exposure of 100mA, 70-74 KV for 0.1 sec. A detailed description of the method of measurement is reported by Garn, (1970). Although several measurements were taken, of particular interest were the total subperiosteal diameter (T), the medullary cavity diameter (M), and the cortical thickness (C).

A pinpoint micrometer caliper (Peacock, Japan) with a 0.05 mm readout capability was used to measure T and M by a radiologist. The measuring error is from 0.10 to 0.15 mm. Intra and interobserver reliability of measures rises to 0.98 or 0.99 with practice.

Bone loss was illustrated by a decrease in cortical thickness due to an increased medullary cavity width. The second metacarpal was used because it corresponds with the cylindrical model necessary for calculating cortical thickness. Also, all or most of the bone tissue is contained within the T and M boundaries. Finally, the second metacarpal is least subject to morphological variations as might occur in chromosomal or genetic abnormalities (Garn, 1970).

Dietary Data

A three day dietary recall, including two weekdays and one weekend day, was collected from each subject. The subjects were given verbal instruction by the tester on the method of recording food intakes on the Diet Information Form found in Appendix D. Forms were returned, checked with the tester for completeness and accuracy, and then processed by the Nutri-Profile Computer Analysis program operated by the Faculty of Human Ecology, at the University of Manitoba. The nutritional breakdown of each subject's diet and the following dietary variables were obtained; protein (g), carbohydrate (g), fat (g), Vitamin D (ug), calcium (mg), phosphorus (mg) and caloric (kcal/day) intakes. A sample printout is presented in Appendix E.

Hemoglobin

A blood sample was taken from the antecubital vein. The sample was extracted by a registered Laboratory Technologist and analyzed for hemoglobin levels using the Sigma Total Hemoglobin Kit. For a detailed description of the blood analysis, see Appendix F.

Statistical Analysis

Exercise variables variables consisted of maximal oxygen uptake (ml/kg /min), grip strength (kg), body fat (%), sum of skinfolds (mm), peak torque during knee extension (Nm/kg) and peak torque during knee flexion (Nm/kg).

Two bone density variables, cortical area (mm) and percent cortical area, and hemoglobin concentration (g/100 ml) were also considered in the final analysis.

Dietary variables measured were calcium (mg), phosphorus (mg), Ca:P, Vitamin D (ug), protein (g), fat (g), carbohydrate (g) and caloric intake (kcal/day).

The mean and the standard deviation of each variable was calculated for the whole population and for each group. The Pearson Product Moment Method was used to determine the degree of association between the above variables for the entire population. The Mann-Whitney Wilcoxon Rank Sum Method was used to ascertain the significance of differences be-

tween the active and sedentary groups for all variables. Prior to analysis, a significance level of $p \leq 0.05$ was established.

RESULTS AND DISCUSSION

The purpose of this study was to determine the relationship between fitness level, bone density, and dietary habits in postmenopausal females aged forty-eight to sixty-five years. These variables were also compared in active and sedentary females of the same age group.

Pearson Product Moment correlations were used to determine the degree of association between several variables in the group as a whole. The subjects were then divided into active and sedentary groups on the basis of maximal oxygen uptake. The Mann-Whitney Wilcoxon rank sum method was used to established the significance of differences occuring in variables between the active and sedentary subjects.

Whole Group Analysis

Physical Characteristics

TABLE 1

Physical characteristics of postmenopausal females (N=28)

	AGE(yr)	HT(cm)	WT(kg)	FAT(%)	SS(mm)*
MEAN	57.14	161.36	59.56	35.26	63.34
S.D.	4.48	4.94	7.53	5.34	23.98

* sum of skinfolds

The physical characteristics of the entire group are presented in Table 1. The group mean body fat (35.2%) was much higher than that reported by Drinkwater et al., (1975) for the same age group (27%). This was due to the fact that the inactive group contained seven subjects with a body fat of over 39%, suggesting that the present sample did not accurately represent older females. The study tended to attract those individuals who were either highly trained, or those who had been sedentary for an extended period of time, and participated in the testing in order to discover lifestyle changes necessary to improve fitness levels.

Skinfolds have commonly been used to determine percent body fat (Milne & Lonergan, 1977) and the sum of skinfolds (Adams & deVries, 1973). In the present study the sum of the four skinfold measures was also calculated and compared to Canadians of the same age and sex, revealing that the group fell into the 55th percentile. Body fat was found to be significantly correlated with body weight (0.67).

Fitness Characteristics

TABLE 2

Fitness characteristics of postmenopausal females (N=28)

	$\dot{V}O_2$MAX (ml/kg/min)	GRIP (kg)	KE60" (Nm)	KE60" (Nm/kg)	KF60+ (Nm)	KF60+ (Nm/kg)
MEAN	31.40	28.0	93.54*	1.61*	61.16*	1.05*
S.D.	8.30	2.50	18.13	0.37	7.65	0.19

* N=26

"Peak Torque during knee extension at 60°/s.

+Peak Torque during knee flexion at 60°/s

Average values for fitness variables are found in Table 2. The mean maximal oxygen uptake of 31.4 ml/kg/min was average for this age and sex according to the Canadian Standardized Test of Fitness (Fitness and Amateur Sport, 1981).

Shoenfeld et al., (1981) tested 3000 males, twenty to sixty years of age and found a decrease in maximal oxygen uptake with advancing age. This is in agreement with the present study where a negative correlation existed between maximal oxygen uptake and age (-0.54). Similar results were found in 104 females aged ten to sixty-eight years, where maximal oxygen uptake decreased and body fat increased with age (Drinkwater et al., 1975). In the present study maximal oxygen uptake was found to be negatively but not significantly correlated with millimetres of body fat (-0.57).

The average grip strength of the non-dominant hand, as measured by the grip dynamometer, was 28.0 kg which was above average (24.0 kg) for this sex and age group (Fitness and Amateur Sport, 1981). The present average grip strength was also greater than that reported by Sinaki et al., (1974) who studied muscle strength in relation to bone mineral content in 85 normal females aged nineteen to eighty-nine. These researchers found that the average isometric, non-dominant grip strength in fifty to sixty-five year old females was similar to the reported Canadian norms of 24 kg, and decreased with increasing age. The present study also found a negative relationship between age and grip strength, but neither study established a relationship between skeletal health and grip strength.

Leg strength during knee flexion and extension (peak torque) was determined by the Cybex II isokinetic dynamome-

ter and expressed in newton metres and newton metres per kilogram of body weight. Average scores are found in Table 2. Significant correlations existed between leg flexion (Nm/kg) and weight (-0.73); leg flexion (Nm/kg) and sum of skinfolds (-0.67); and weight and sum of skinfolds (0.67). These correlations suggest that the heavier individuals with greater body fat exhibited less leg strength, probably due to inactivity. There existed a weak correlation between grip strength and leg flexion (Nm/kg), (0.56) indicating a lack of congruency between upper and lower body strength.

Bone Density

TABLE 3

Bone density characteristics of postmenopausal females (N=28)

	CORTICAL AREA (mm)	CORTICAL AREA (%)
MEAN	0.43	81.72
S.D.	0.07	8.15

The bone density characteristics of the subjects are found in Table 3. Bone density is often expressed as cortical area or percent cortical area. As previously discussed, bone density decreases in late adult life, and this decrease can be assessed by measuring the thickness of the cortical

layer of bone in terms of absolute area and percentage of total area (Garn, 1970). The average percent cortical area of the present group was 81.72% which is slightly higher than the average (78.80%) found in a three country, 13,000 subject study by Garn et al., (1967). When only American data was considered by Garn et al., (1967), however, the average percent cortical area was 81.30% which is in agreement with the present group (81.72%). Although no significant correlations existed between cortical area (percent or milimetres) and the other test variables, a weak negative relationship was noted between percent cortical area and age (-0.56). This is in agreement with reports of a decrease in percent cortical area with increasing age (Garn et al., 1967; Milne & Lonergan, 1977).

Dietary Variables

TABLE 4

Dietary intake of postmenopausal females (N=28)

	PROT(g)	FAT(g)	CHO(g)	KCAL
MEAN	77.21	62.72	192.12	1665.21
S.D.	17.64	18.76	63.24	393.47

TABLE 5

Nutrient intake of postmenopausal females (N=28)

	VIT D(ug)	CA(mg)	PH(mg)	CA:PH
MEAN	4.80	906.46	1339.67	1:1.5
S.D.	3.74	362.27	360.04	-

Dietary data is presented in Tables 4 and 5. Three day diet records were collected from each subject and then analyzed to determine nutrient adequacy. Three days of self-reporting was considered to be most accurate, as previous studies have found one day food records to be accurate only for large sample groups (over 500 subjects). One day food records have also been reported to inaccurately represent daily food intakes, and to underestimate caloric intakes. The percentage of subjects adhering to self recording generally decreases as the number of days required to record increases, and because 7 day diet histories tend to overestimate protein intakes, this method was thought to be inappropriate for the present study group (O'Hanlon & Kohrs, 1978).

The average daily energy intake for the group was 1665.61 kcal. O'Hanlon and Kohrs (1978) studied dietary intakes of older Americans (over 59 years) and found females took in an average of 1734 kcal per day, which is comparable to the

present study. Although the average energy intake for this group was slightly lower than the average Canadian intake, the reportedly high body fat of the present group indicates either an underestimation of caloric intakes, low activity levels, or both.

Mean protein intakes were found to be more than adequate at 77.21 g or 1.30 g per kg body weight. This is 17% of the total caloric intake. The Canadian Dietary Standard (Health and Welfare Canada, 1983) set the recommendation at 0.7 g per kg body weight or, 12 to 15% of total caloric intake. Harper (1978) noted that protein needs of young and elderly adults do not differ because as muscle mass decreases with age, so does the rate of turnover of total body protein. A protein level of 12% of total intake is thought to provide adequate trace minerals and iron without imposing an excessive load on the kidneys. As well as stressing the renal function, an excessive protein intake has been shown to increase urinary calcium, causing a negative calcium balance, and bone loss (Licata et al., 1981; Lutz & Linkswiler, 1981).

Average dietary fat consumed was 62.27 g or 34% of the total caloric intake, which is lower than the Canadian average intake of 42% fat (National Research Council, 1980), but compatible with the 35% dietary fat recommended by the Handbook of Clinical Dietetics (American Dietetic Association, 1981). Although energy needs decline with age, because of a

slower metabolic rate, nutrient requirements do not. This places the elderly individual at risk as it becomes increasingly difficult to meet nutrient needs on an energy reduced diet (Harper, 1978). Therefore, the Report of the Committee on Diet and Cardiovascular Disease (Health and Welfare Canada, 1976) recommended a decrease in fat consumption by the elderly in favour of cereals, vegetables and fruits, resulting in a diet with a higher ratio of essential nutrients to calories. A decrease in fat intake is also recommended because a high fat diet has been shown to decrease calcium absorption by binding with calcium and forming insoluble calcium salts (Stare & McWilliam, 1977).

Carbohydrate contributed an average of 46% of total energy intake for subjects in the present study. The Canadian Dietary Standard (Health and Welfare Canada, 1983) recommended a consumption of 50% carbohydrates in the average diet. The present group was slightly below the recommended level, however, it has been suggested that the elderly should limit carbohydrate, as well as fat intake, in favour of vitamin and mineral rich protein foods (Krause & Mahan, 1979). The nature of the carbohydrate consumed is important since the elderly have a reduced glucose tolerance and are more subject to hypo and hyperglycemia (Krause & Mahan, 1979). Simple sugars which are quickly absorbed should be avoided in favour of more complex, starchy carbohydrates, such as grains and lentils, as these are more slowly metabo-

lized and absorbed, and contain valuable B Vitamins, iron and fiber (Krause & Mahan, 1979).

Average vitamin D intake of the group was 4.80 ug , which was determined adequate by the Canadian Dietary Standard (Health and Welfare Canada, 1983). The elderly population has demonstrated reduced fat and fat soluble vitamin absorption. Since Vitamin D is fat soluble, and its absorption is necessary for calcium deposition in the bone, adequate intake is essential. However, inadequate Vitamin D intake is rare as milk and margarine are fortified with this nutrient.

The mean calcium and phosphorus intakes were 900.46 mg and 1339.67 mg respectively and the Ca:P ratio was 1:1.5. Calcium is one of the nutrients most often found to be deficient in diets of individuals, especially females, over fifty-nine years (O'Hanlon & Kohrs, 1978). The Canadian Dietary Standard (Health and Welfare Canada, 1983) advocated a daily calcium intake of 800 mg/day for adult females which the present group exceeded. Jowsey (1978), however, recommended an intake of 1 gm/day for premenopausal females, and 1.5 gm/ day for postmenopausal females, in order to offset the decrease in calcium absorption, and subsequent decline in skeletal health that occurs with age. Harper (1978), however, found no evidence to indicate that an increased calcium intake would reduce the bone loss occurring with age.

The Canadian Dietary Standard (Health and Welfare Canada, 1983) determined the average western diet to contain approximately 1600 mg of phosphorus per day, whereas the present group consumed an average of 1339.67 mg daily. High dietary phosphorus has been shown to cause diarhhea and bone resorption in human subjects (Bell et al., 1977). However, phosphorus intake alone is not responsible for bone loss, but rather the ratio of Ca:P in the diet must be examined. The recommended ratio is 1:1.6, compared to the present group value of 1:1.5. Since a ratio of 1:2 has been shown to contribute to bone resorption, the lower Ca:P ratio found in the present group is compatible with optimal bone health (Draper & Scythes, 1981).

Hemoglobin

The average hemoglobin value for the present group was 12.95 (± 1.37) gms/100 ml whole blood. This is well within the normal range for females (12 to 16 gms/100 ml whole blood) (Parr et al., 1984). Hemoglobin values for this age group would be expected to be higher than premenopausal females as monthly menstrual losses would be eliminated. The normal hemglobin status of this group indicates that hemolysis occurring due to overtraining was not serious enough to cause a perceptible decrease in hemolglobin. Perhaps training was not of the intensity or duration to cause a change in this blood parameter.

Active vs Sedentary Females

Subjects were divided into active or sedentary groups on the basis of a questionnaire (Appendix A) and predicted maximal oxygen uptake. Due to the small sample size, the Mann-Whitney Wilcoxon Rank Sum method was used to investigate the possibility of significant differences in variables between active and sedentary subjects. A confidence level of $p \leq 0.05$ was established.

Physical Characteristics

TABLE 6

Physical characteristics of active and inactive postmenopausal females

	AGE	HT(cm)	WT(kg)	FAT(%)	SS(mm)*
ACTIVE(N=11)					
MEAN	54.73**	159.84	55.18**	32.75**	51.15
S.D.	3.64	5.29	6.49	4.43	13.63
INACTIVE(N=17)					
MEAN	58.70**	162.34	62.38**	36.88**	71.23
S.D.	4.36	4.58	6.91	5.35	25.95

*Sum of Skinfolds

**significant at $p \leq 0.05$

The physical characteristics of the active and sedentary subjects are found in Table 6. Active subjects were significantly younger, lighter and had less body fat (percent) than sedentary subjects. This is consistent with the findings of Drinkwater et al., (1975) who reported that female subjects with above average aerobic power for age had significantly lower percent body fat than their sedentary counterparts. The fact that the older women had higher body fat and were less active indicates that perhaps it is inactivity rather than age which precipates the higher weight and body fat. This was illustrated by Pollock et al., (1974) who examined physiological characteristics of elite American male track athletes, forty to seventy-five years of age. Average body fat ranged from 11.2% for the 40 to 49 age group and 13.6% for the 70 to 75 age group. The average body fat for a sedentary male over 70 years of age is 26% (Fitness and Amateur Sport, 1981). Pollock et al., (1974) illustrated that the effects of aging on body fat were not as apparent in the older active male.

Fitness Characteristics

TABLE 7

Fitness characteristics of active and inactive postmenopausal females

	$\dot{V}O_2$MAX (ml/kg/ min)	GRIP (kg)	KE60* (Nm)	KE60 (Nm/kg)	KF60* (Nm)	KF60 (Nm/kg)
ACTIVE(N=11)						
MEAN	39.61**	28.50	97.85	1.78	64.45	1.18**
S.D.	4.56	2.97	15.23	0.31	6.40	0.16
INACTIVE(N=17)						
MEAN	26.08**	27.59	90.40	1.48	58.74	0.95**
S.D.	5.08	2.26	19.90	0.36	7.78	0.17

* N=15

**significant at $p \leq 0.05$

Analysis of fitness variables (Table 7) revealed a forced significant difference in maximal oxygen uptake as subjects were separated into active and sedentary groups on the basis of this parameter. There was a significant difference in peak torque during knee flexion at 60°/s, but only when corrected for body weight. No significant difference was noted in grip strength between the active and sedentary group.

Adams and deVries (1973) examined fitness variables in females aged 52 to 79 years, and found that significant fitness gains could be accomplished through a moderate jog-walk program. No mention was made of bone density, though one can assume from previous research that an increase in bone mineral would occur with activity (Smith, 1982).

Bone Density

TABLE 8

Bone density of active and inactive postmenopausal females

	CORTICAL AREA(mm)	CORTICAL AREA(%)
ACTIVE(N=11)		
MEAN	0.41	84.65
S.D.	0.07	7.3
INACTIVE(N=17)		
MEAN	0.45	79.83
S.D.	0.06	8.29

Bone density data is found in Table 8. It was observed that neither cortical area nor percent cortical area were significantly different in active and sedentary subjects, although the percent cortical area approached significance

at $p \leq 0.06$. Oyster et al., (1984), however, found the cortical diameter to be significantly wider in physically active female subjects. This significant finding may have been attributed to subject selection from each end of a physical activity continuum, as determined from a questionnaire. The mid range activity levels were dropped, whereas the present study did not drop subjects falling in the middle of the fitness continuum.

Numerous studies have illustrated the positive effects of activity on skeletal health. Doyle et al., (1970) examined the relationship between bone mass and muscle mass in 47 male and female cadavers (average age was 57.2 years). It was found that the weight of the psoas muscle was significantly and positively correlated to the ash weight of the third lumbar vertebrae, suggesting that the larger muscle was related to denser, heavier bones. The phenomena of peizoelectricity was discussed earlier, and it would appear that a muscle hypertrophied through exercise would exert greater force on the tendinous articulation and lead to a stronger healthier bone. Emiola and O'Shea (1978) studied the effects of physical activity on the bone density of 90 male and female university students 20 to 25 years of age. Bone density was determined by X-rays of the second phalangeal segment of the small finger of the right and left hand, and by measuring cortical density. It was found that the high activity group had a significantly denser bone than the

moderate and low activity group and that males had significantly denser bones than females. Although the present data revealed no significance differences in cortical density between groups, the methodology or small sample size may have prevented significant findings.

Dietary Variables

TABLE 9

Dietary intake of active and inactive postmenopausal females

	PROT(g)	FAT(g)	CHO(g)	KCAL
ACTIVE(N=11)				
MEAN	74.37	61.01	191.18	1645.45
S.D.	18.52	20.77	64.02	403.53
INACTIVE(N=17)				
MEAN	79.05	63.84	192.74	1678.65
S.D.	17.35	17.91	64.71	398.77

Dietary data for active and sedentary postmenopausal females is found in Table 9 and Table 10. Analysis of three

TABLE 10

Nutrient intake of active and inactive postmenopausal females

	VIT D(ug)	CA(mg)	PH(mg)	CA:P
ACTIVE(N=11)				
MEAN	5.18	877.57	1302.24	1:1.4
S.D.	3.76	403.49	406.16	-
INACTIVE(N=17)				
MEAN	4.55	925.15	1363.89	1:1.4
S.D.	3.83	344.63	337.73	-

day dietary intake revealed no significant differences in dietary or nutrient intake between the active and sedentary groups. It was interesting that total caloric intake was similar, but weight and body fat were higher in the sedentary group. As previously mentioned, this could be accounted for by an underestimation of self reported caloric intakes and/or low activity levels in the sedentary group.

The mean calcium intake of both groups exceeded the Canadian Dietary Standard (Health and Welfare Canada, 1983) recommendation of 800 mg per day, but neither group met the 1.5 gram per day level recommended by Jowsey (1978) and Mar-

cus (1982) for postmenopausal females. Seeman and Riggs (1981) stated that this increased need for calcium arises from a decline in calcium absorption with aging, resulting in an increased calcium requirement to maintain skeletal integrity. In the present study, both active and sedentary groups had an average Ca:P ratio of 1:1.5. The average Western diet, with a ratio of 1:1.6, appears to be satisfactory for the maintenance of skeletal health (Draper & Scythes, 1981).

Although insignificant, Vitamin D intake appeared to be higher and protein intake lower in the active group. Higher Vitamin D and lower protein intake has been shown to enhance calcium absorption and decrease urinary calcium losses (Aloia et al., 1983; Licata et al., 1981). Both the active and inactive groups adequately met Vitamin D recommendations and were overconsumers of protein. Oyster et al., (1984) was in agreement with the present study, in that there were no significant differences in dietary intakes between active and sedentary postmenopausal females, but unlike the present study, active subjects had significantly greater bone mass. These studies point to the uncertainty as to whether nutrient adequacy affects bone health. Smith and Frame (1965) looked specifically at calcium in an epidemiological study involving 2063 females and found that changes in mineral content and bone density were unrelated to calcium intake. The idea that calcium intake is not as important in bone

health as previously thought has been investigated by Harper (1978), who stated that it is accepted that calcium is lost from the skeleton with aging but debatable as to whether increases in intake above the Canadian Dietary Standard (Health and Welfare Canada, 1983) can reduce the loss.

Hemoglobin

Average hemoglobin values for the active and sedentary groups were 12.64 (± 1.46) and 13.15 (± 1.32) respectively. There was no significant difference in hemoglobin values between the two groups, both of which had levels well within the normal range for females. This is in agreement with Parr et al., (1984) who examined female athletes participating in track and field, softball and field hockey, and found mean hemoglobin values of 14.0 (±0.8) to 14.3 (±0.7). Sedentary controls were found to have a mean value of 13.9 (±0.8). It was found that stage 1 and 2 iron deficiency existed in female athletes, as indicated by below normal levels of serum ferritin, serum iron and transferrin saturation as well as reduced total iron-binding capacity. The levels of the above intermediates of iron metabolism were significantly lower in the active females than in the sedentary controls.

In conclusion, the maintenance of skeletal integrity is a multifactorial process involving adequate calcium and Vitamin D levels, moderate protein and phosphorus levels, as well as regular weight bearing activity.

Research has shown that exercise has positive effects on skeletal health. Although the present study found no significant correlations between bone density and any fitness variable, significant correlations were found between activity and both maximal oxygen uptake and peak torque during leg flexion (Nm/kg). As well, the difference in percent cortical area between active and inactive subjects approached significance.

A negative relationship was noted between bone density and age which may indicate that as females advance in age, bone loss could occur unless preventative measures are taken. Although no relationship was found between nutrient intake and bone health, it is believed that consuming a diet adequate in all nutrients, as well as participation in regular activity, are prudent steps in the pursuit of optimal bone health.

SUMMARY AND CONCLUSIONS

The purpose of this paper was to examine bone density and nutrient intake in active and sedentary postmenopausal females. When considering the group as a whole it was found that body fat was significantly correlated (0.67) with body weight. As well, significant correlations existed between peak torque during knee flexion (Nm/kg) and body weight (-0.73); and peak torque during knee flexion (Nm/kg) and sum of skinfolds (-0.76). There existed a negative correlation between age and cortical area (-0.56); age and maximal oxygen uptake (-0.54); and body fat and maximal oxygen uptake (-0.57).

Dietary analysis revealed that the group consumed adequate Vitamin D, calcium, and phosphorus, according to the Canadian Dietary Standard (Health and Welfare Canada, 1983). Fat consumption of the group was not excessive and the contribution of carbohydrates to the diet approached the recommended level. Energy intake was determined adequate as all nutrient needs were met. No significant correlations were noted between dietary variables and bone density.

When considering active and sedentary individuals, the active females were significantly younger, lighter and had less body fat than their sedentary counterparts. The active

group had significantly greater maximal oxygen uptake and peak torque during leg flexion (Nm/kg) at 60^{o}/s. There was no significant difference in bone density between groups, although the difference in percent cortical area approached significance.

On the basis of this study the following conclusions can be made:

1. Physical characteristics illustrated that the active group had less body fat and weighed less than their sedentary counterparts.
2. The lower body fat of the active subjects illustrates the importance of exercise in weight control.
3. Fitness characteristics indicated that the active group had significantly higher predicted maximal oxygen uptakes and greater peak torque during knee flexion at 60^{o}/sec than their sedentary counterparts.
4. Bone density did not significantly vary between groups.
5. Nutrient intake did not differ in active and sedentary individuals and all subjects consumed adequate amounts of all nutrients.
6. Hemoglobin values did not differ between groups and all were in the normal concentration range.

Recommendations

The following recommendations were formulated from the results of this study:

1. The present study illustrated the need for further research into preventative lifestyle habits for individuals at risk for osteoporosis.
2. To better elucidate the effects of nutrient intake and exercise on skeletal health, the researcher should intervene by placing subjects on a specific diet and exercise plan, and measure bone health before and after intervention.
3. Future research should increase the number of bone sites measured in order to obtain a more accurate analysis of bone health.
4. Future research should examine other types of weight bearing activities which may not necessarily improve maximal oxygen uptake, but may in fact improve skeletal health.

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Appendix A

QUESTIONNAIRE

All information in this document will be kept confidential.

Please answer YES or NO to the following questions.

1. Are you over 20 pounds overweight?_____
2. Do you smoke?_____
3. Do you reside in a flouridated area?_____
4. Are you Caucasian?_____
5. Are you undergoing hormone therapy now?_____
6. Have you undergone hormone therapy in the past five years?_____
7. Are you six months postmenopausal?_____If no, how many months?_____
8.

Please answer the questions in the next section as CAREFULLY as possible.

1. How many times a week do you engage in physical activities in which you exert yourself enough to cause a sweat? For what duration do you maintain this level? Times/week. none_____once_____twice_____ three_____four_____more_____(number) Duration. 0

min._____10 min._____15 min._____20 min._____30 min. _____more_____(minutes)

2. Do you maintain this activity level year round? yes_____no_____ explanation (if necessary)_____

3. For how many months/years have you maintained this activity level?

_____

4. Does this level of activity reflect life long activity patterns?

yes_____no_____explanation_____

5. How many alcoholic drinks do you consume in one week?(One drink equals one beer or one ounce hard liquor or one six ounce glass of wine).

1.____2.____3.____4.____5.____6.____7.____8.____9.____10.____

6. Are you currently taking any vitamin/mineral supplements? If so, please state what you are taking?_____

7. Are you taking a protein supplement? If so, please state the name brand

_____

8. Have you been seriously ill in the past year? If so, please state the nature of your illness._____

9. Do you suffer from any of the following? arthritis_____bone or joint disorders_____kidney disorders_____digestive ailments_____

10. Are you presently taking any medication? If so, please state what you are taking and why._____

Appendix B

INFORMED CONSENT

Explanation of the Tests

Cycle Ergometer

This a submaximal (not to exhaustion), three-stage test, where your heart rate is monitored every minute and is expected to be in the range of 120 to 170 beats per minute. The three stages indicate that there will be an increment in the workload every four minutes. Your maximal oxygen uptake will be calculated from an average of your last two heart rate measures. If you feel discomfort at any time during the test, you are free to stop.

Grip Strength

This test involves maximally squeezing a hand grip dynamometer for a duration of two to three seconds. This is done with both hands, and the best scores of two trials from each hand will be added together.

Cybex

This is an isokinetic dynamometer involving flexion and extension of the hip and knee at maximal speed. Torque or rotary speed will be measured.

Body Fat

This will involve measuring skinfolds at four different sites of the body. The locations of the sites are at the triceps, biceps, subscapularis (shoulder blade), and the suprailiac (hip bone). The measures will be taken at least twice and not more than three times at each site and body fat estimated from these measures.

Blood Test

A fasting blood sample will be taken from the right arm by a laboratory technologist. The sample will be taken first thing in the morning, and you are asked not to eat or drink anything until after the sample is obtained. This is the only invasive test you will be asked to participate in.

Diet Recall

You will be asked to record all foods eaten on three separate days: Two weekdays and one weekend day. Please try to pick those days that you feel closely resemble your normal eating patterns. Accuracy is imperative, therefore, all

"extras"; margarine, salad dressing, and amounts must be recorded. You will be asked to meet with the nutritionist with your food records at a time suitable for you. At this time your records will be examined to ensure accuracy of recording. You will receive, at a later time, information concerning the nutrient adequacy of your diet.

Bone Density

You will be asked to report to the Health Science Center Rehabilitation-Radiology Department at a pre-arranged time. An X-ray will be taken of your non-dominant hand to assess your bone density. Radiation risks are minimal, in fact, the radiation exposure is less than that experienced during routine dental X-rays. You are free, however, to consult with your doctor concerning potential harmful effects to you, personally. If your doctor advises against the procedure, you are free to with draw from the study.

Privileged Use of Information

Your X-rays will be kept by the researcher. All other information will remain strictly confidential. You will have access to your personal results only. No names will appear in the final thesis report. May I remind you that this is a unique and valuable oppor tunity to obtain information concerning your own personal fitness level, dietary adequacy and skeletal health with minimal risk involed.

Inquiries

Please direct any questions you may have concerning the procedures outlined to Janice Pratt, 477-4969.

Freedom of Consent

Your consent to participate in these tests is voluntary and you are free to deny consent or withdraw from testing at any time.

I have read this document and I understand all testing procedures, that I will perform and that will be performed on me, and give my consent to participate in this study.

Appendix C

PHYSICAL ACTIVITY READINESS QUESTIONNAIRE
(PAR-Q)

PAR Q & YOU

PAR-Q is designed to help you help yourself. Many health benefits are associated with regular exercise, and the completion of PAR-Q is a sensible first step to take if you are planning to increase the amount of physical activity in your life.

For most people physical activity should not pose any problem or hazard. PAR-Q has been designed to identify the small number of adults for whom physical activity might be inappropriate or those who should have medical advice concerning the type of activity most suitable for them.

Common sense is your best guide in answering these few questions. Please read them carefully and check (√) the ☐ YES or ☐ NO opposite the question if it applies to you.

YES	NO	
☐	☐	1. Has your doctor ever said you have heart trouble?
☐	☐	2. Do you frequently have pains in your heart and chest?
☐	☐	3. Do you often feel faint or have spells of severe dizziness?
☐	☐	4. Has a doctor ever said your blood pressure was too high?
☐	☐	5. Has your doctor ever told you that you have a bone or joint problem such as arthritis that has been aggravated by exercise, or might be made worse with exercise?
☐	☐	6. Is there a good physical reason not mentioned here why you should not follow an activity program even if you wanted to?
☐	☐	7. Are you over age 65 and not accustomed to vigorous exercise?

If You Answered

YES to one or more questions

If you have not recently done so, consult with your personal physician by telephone or in person BEFORE increasing your physical activity and/or taking a fitness test. Tell him what questions you answered YES on PAR-Q, or show him your copy.

programs

After medical evaluation, seek advice from your physician as to your suitability for:

- unrestricted physical activity, probably on a gradually increasing basis.
- restricted or supervised activity to meet your specific needs, at least on an initial basis. Check in your community for special programs or services.

NO to all questions

If you answered PAR-Q accurately, you have reasonable assurance of your present suitability for:

- A GRADUATED EXERCISE PROGRAM - A gradual increase in proper exercise promotes good fitness development while minimizing or eliminating discomfort.
- AN EXERCISE TEST - Simple tests of fitness (such as the Canadian Home Fitness Test) or more complex types may be undertaken if you so desire.

postpone

If you have a temporary minor illness, such as a common cold.

Reference: PAR-Q Validation Report, British Columbia Ministry of Health, 1978.
* Produced by the British Columbia Ministry of Health and the Department of National Health & Welfare.

Appendix D

DIET INFORMATION FORM

The following information is used to assess your diet. Please answer all questions.

PERSONAL DATA:

Sex: Female _____ Male _____
Age: Years _____ Months _____
Height: 19 years & over, with 1" heels
cm____ OR ft____ in____
Weight: 19 years & over, with clothing
kg _____ OR lbs _____
Frame: Small____ Medium____ Large____
See information at end of form on how to determine your frame size.

Do you smoke cigarettes? Yes___ No___
If yes, how many per day?_____
Are you pregnant? Yes _____ No_____
Due date: _____
Pre-pregnancy weight: kg___ OR lbs___
Are you nursing? Yes _____ No _____

DIET:

Are you on a special diet? Yes___No___
If yes, what kind?_____
Do you take vitamin or mineral supplements? Yes _____ No _____
If yes, brand name: _____
Dosage per day: _____

FOOD RECORD:

List everything you eat or drink for a 1, 2 or 3 day period or more. The analysis will be more accurate if it is based on a period of at least 3 days. Use a separate line for each item as shown in the example. Include all snacks, soft drinks, cream and sugar in coffee and tea, butter or sauces on vegetables, jams, relishes, candy bars, etc. Be sure to write down how much you eat (metric measures such as mL, g or standard measures such as cups, oz., Tbsp., tsp.). Please print clearly.

Example:

FOOD & DESCRIPTION	AMOUNT
Milk - 2%	200 mL OR 6 oz.
Egg sandwich	
egg-hard boiled	1 medium
butter	10 mL OR 2 tsp.
bread-60% whole wheat	2 slices
mayonnaise	15 mL OR 1 Tbsp
Banana	1 large
White Cake (homemade)	5cmX5cmX7cm OR 2"X2"X2 3/4"
plain butter icing	1/2 cm OR 1/4"

PHYSICAL ACTIVITY:

Estimate the number of hours you spend in each activity category during one 24-hour period. This helps to calculate your caloric needs.

1. Sleeping, resting.
2. Sitting (at home, in car, on bus), eating meals, watching T.V., standing still.
3. Light Activity: walking slowly, light domestic work (eg. cooking, washing dishes, sweeping), light office or industrial work (eg. typing, laboratory work, working with light tools), sports involving light activity (eg. golf, sailing, bowling).
4. Moderate Activity: walking at moderate speed, moderate domestic work (eg. scrubbing floors, cleaning windows), moderate industrial work (eg. painting, modern farming), hobbies involving moderate activity (eg. gardening, wood-working, dancing), sports such as tennis, cycling, skiing, swimming, skating and jogging.

1. _____ + 2. _____ + 3. _____ + 4. _____ = 24 hours (must = 24)
Resting Sedentary Lt. Act. Active

Appendix E

DIETARY ANALYSIS COMPUTER PRINTOUT

TRIENT BREAKDOWN

utrient	Recommended Amount	Your Intake	Percent of Recommended Intake (77% / 100% / 200%)			Percent Value
			At RISK	Low	No Risk	
rotein	53.7 g	66.8 g	**********		**********	124 %
itamin A	800.0 RE	529.8 RE	**********			66 %
itamin C	45.0 mg	113.8 mg	**********		**********	253 %
itamin D	2.5 ug	6.2 ug	**********		**********	249 %
hiamin	0.8 mg	1.0 mg	**********		*****	121 %
iboflavin	1.0 mg	1.8 mg	**********		**********	179 %
iacin	14.4 NE	23.2 NE	**********		**********	161 %
itamin B6	1.0 mg	1.7 mg	**********		**********	169 %
olacin	165.0 ug	170.3 ug	**********			103 %
itamin B12	2.0 ug	4.1 ug	**********		**********	206 %
antothenic Acid	3.5 mg	4.8 mg	**********		*******	138 %
alcium	800.0 mg	1,025.3 mg	**********		*****	128 %
hosphorus	800.0 mg	1,187.3 mg	**********		********	148 %
on	7.0 mg	9.6 mg	**********		*******	137 %
otassium	54.4 mEq	71.4 mEq	**********		******	131 %
odium	29.0 mEq	68.3 mEq	**********		**********	235 %
ber, Crude		3.8 g				

sk" means that an individual may not have met his/her requirement.

Appendix F

HEMOGLOBIN ANALYSIS

Calibration

1. Working standards were prepared by mixing 0.0 ml and 6.0 ml, 2.0 ml and 4.0 ml, 4.0 ml and 2.0 ml, 6.0 ml and 0.0 ml of Cyanmethemoglobin Standard Solution and Drabkins Solution, respectively.
2. Absorbance was read on a Bausch and Lomb Spectrophotometer at a wavelength of 540 nm.
3. A calibration curve of absorbance values was plotted.

Procedure

1. Drabkin's Solution (5.0 ml) was added to each test tube.
2. The solution was mixed and allowed to stand at room temperature for 15 minutes.
3. Absorbance was read and recorded.
4. Total hemoglobin concentration (g/100 ml) was determined directly from the calibration curve.