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TITLE: RADIOGRAPHIC ASSESSMENTS OF BONE DENSITY IN CARDIAC-PRONE ADULTS PARTICIPATING IN A 12-MONTH PHYSICAL CONDITIONING PROGRAM

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Purpose of the Study

The purpose of this study was to investigate the effects of a 12-month physical activity (jogging) program on the bone density of cardiac-prone participants in the Adult Fitness Program at the University of Wisconsin-La-Crosse.

The following null hypotheses were tested:

1. There was no significant difference in bone density measurements of adults due to the 12-month physical activity program.

2. There was no significant difference in bone density measurements of adults due to the 12-month physical activity program when sex was considered.

Procedures/Results

Seven male and five female cardiac-prone participants in the Adult Fitness Program at the University of Wisconsin-LaCrosse volunteered to be subjects for this study. The quantitative radiographic technique was utilized to assess bone density initially and again nine and 12 months thereafter (April 1979 - April 1980). All data were collected by the investigator.

The paired t-test was used to test null hypothesis 1. Null hypothesis 1 was rejected. There were statistically significant increases in bone density measurements of the adults in this study due to a 12-month physical activity (jogging) program. The one-way analysis of covariance was used to test null hypothesis 2. Null hypothesis 2 was rejected. Females in this investigation experienced a significantly greater increase in bone density than males for both the nine-month and 12-month measurements.

Conclusions

The following conclusions have been drawn from the results of this investigation:

1. The physical activity program as outlined in this study increased bone density of cardiac-prone adults in the Adult Fitness Program at the University of Wisconsin-LaCrosse.

2. Cardiac-prone females (age 31-62) realized a greater increase in bone density as a result of the physical activity program as outlined in this study than cardiac-prone males (age 31-45).

RADIOGRAPHIC ASSESSMENTS OF BONE DENSITY IN CARDIAC-PRONE ADULTS PARTICIPATING IN A 12-MONTH PHYSICAL CONDITIONING PROGRAM

by

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for SANDRA PRICE

DEDICATION

This thesis is dedicated to my family for without their love, faith, and encouragement this goal may never have been attained.

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CHAPTER I

INTRODUCTION

Why the human body grows old and eventually dies has been a question of concern for many years reflecting man's long interest and desire to learn about the aging process (17). Research indicates that a general lack of physical activity causes a deterioration in the proper functioning of the body systems thus accelerating the processes of aging. However, many cultures decree that the "habitual activity of a person should diminish with age" (70).

Loss of skeletal mass, or decrease in bone density, appears to be associated with the aging process. This decrease in bone density in the aged is defined as senile or idiopathic osteoporosis. Gordon and Vaughn (31) define osteoporosis as "poverty of bone tissue; literally not enough bone is present."

Osteoporosis appears to be a form of disuse atrophy of the skeletal system (72). Research has established that the strength of bone is dependent, to some extent at least, upon the amount of stress and strain exerted upon it (64). However, throughout the United States machines now supply the power for most jobs, eliminating such common physical activity as walking, running, lifting, and climbing (83). Bone loss is recognized as a complication of bed rest, immobilization of a limb, or loss of gravitational stimuli due to space travel (10, 36, 42). Insufficient bone tissue leads to increased porosity, brittleness and rarefaction of normally mineralized bone which ultimately results in pathologic fragility of the skeleton (31, 42).

Fractures of osteoporotic origin constitute one of the major disabling afflictions of the elderly. According to the National Disease and Therapeutic Index-Diagnosis, in 1971 there were about 2,500,000 patient visits for the treatment of osteoporosis. In 1978, Albanese et al. (8) stated there were 6,000,000 osteoporotic fractures in the United States.

In short, disuse atrophy of the skeleton, or osteoporosis, is becoming a major health problem in the United States.

Need for the Study

The need to develop a form of therapy which prevents bone loss is apparent. The greatest rate of bone mineral content decline in cross sectional studies was observed between the ages of 45 and 70 (49). The causes of this decline are hypothesized to be many, two of which are inactivity and decreased calcium intake and absorption (73).

A relationship does appear to exist between activity and bone mass at all levels of stress (6, 27, 74). For example, manual laborers have more bone mass than sedentary workers, who in turn have more than bedridden or immobilized people. It is reasonable to deduce, therefore, that a sedentary life style will contribute to bone loss (42).

In a cross sectional study, Emiola and O'Shea (27) by way of a physical activity inventory, divided college students into three physical activity groups: high, moderate, and low. Using the quantitative radiographic technique, bone density was assessed. The results of their study revealed that there was a significant difference in bone density as a function of the physical activity level. The highly active group had more dense bone than the moderate and low active groups.

Research to date indicates that physical activity may positively effect bone density and, therefore, may be a possible treatment for osteoporosis. Because of this apparent influence on bone health, a definite need exists to determine if a regularly prescribed exercise program of specific intensity and duration can positively effect bone density in adults.

Purpose of the Study

The primary purpose of this study was to determine the effects of a 12-month physical activity (jogging) program on the bone density of cardiac-prone participants in the Adult Fitness Program at the University of Wisconsin-LaCrosse. The secondary purpose was to compare male and female subjects to determine if a relationship existed between sex and alterations in bone density due to a specific level of physical activity.

Hypotheses

The null hypotheses tested in this study were:

1. There was no significant difference in bone density measurements of adults due to the 12-month physical activity program.

2. There was no significant difference in alterations in bone density due to the 12-month physical activity program when sex was considered.

Delimitations of the Study

This study was delimited to seven male and five female cardiac-prone volunteer subjects who were participants in the Adult Fitness Program at the University of Wisconsin-LaCrosse. The subjects ranged in age from 31 to 62 years with the average for females being 45.5 and males 38.

Limitations of the Study

1. The small number of cardiac-prone subjects available at any one time willing to serve as subjects;

2. The attrition rate inherent in studies of a longitudinal nature;

3. The lack of randomness due to the fact that subjects were volunteers;

4. The age range of the subjects who participated in the study for the full 12-month period.

Definition of Terms

It seems advisable to define and clarify the meaning of the following terms as they are used in this report; other terms or phrases used in the text are self-explanatory.

Adult Fitness Program. A health maintenance program emphasizing cardiovascular endurance, flexibility, and nutrition.

Bone Density. The mass of bony tissue per unit volume of bone.

Calcium Balance. The net excess or deficit of retention of the element as compared to intake.

Calcium Metabolism. The total sum of the process by which calcium enters and leaves the body.

Calcium Intake. The amount of calcium an individual consumes per day.

Cardiac-prone. Individuals who possess any combination of three or more of the following coronary risk factors directly associated with heart disease: overweight, cigarette smoking, diabetes, sedentary life style, high serum lipids, hypertension, heredity.

HGH. Human growth hormone secreted by the anterior pituitary gland.

Longitudinal. Research studies of one year or more in duration.

Ossification. The process by which calcium is deposited within the bone tissue. Sometimes referred to as calcification.

Phalanx 5-2. The second phalangeal segment (middle) of the small finger.

PTH. Parathyroid hormone secreted by the parathyroid gland.

RDA. Recommended Daily Allowance of vitamins and minerals prepared by the Food and Nutrition Board, National Academy of Sciences-National Research Council.

CHAPTER II

REVIEW OF LITERATURE

In the "normal" adult skeleton the rate of bone formation is in balance with bone resorption so that the total amount of bone mineral is kept constant. However, bone loss is a universal phenomenon of aging, increasing with advanced years in both males and females resulting in a condition termed osteoporosis (73). One of the persistent obstacles in studying this disease has been the lack of simple objective methods to detect bone loss in patients before fractures occur. However, the refinement of the quantitative radiographic densitometric method of bone density assessment has enhanced the study of this apparent aging problem (5).

This chapter includes a survey of the literature on: bone composition, importance of calcium in the body, calcium metabolism, bone remodeling, osteoporosis, age and sex, nutrition, physical activity, methods of bone density measurement, and site of measurement.

Bone Composition

All bones of the body, even though they vary in size and shape, have the same basic structure. Figure 1 shows the cortex, trabeculae and marrow cavity of the femur.

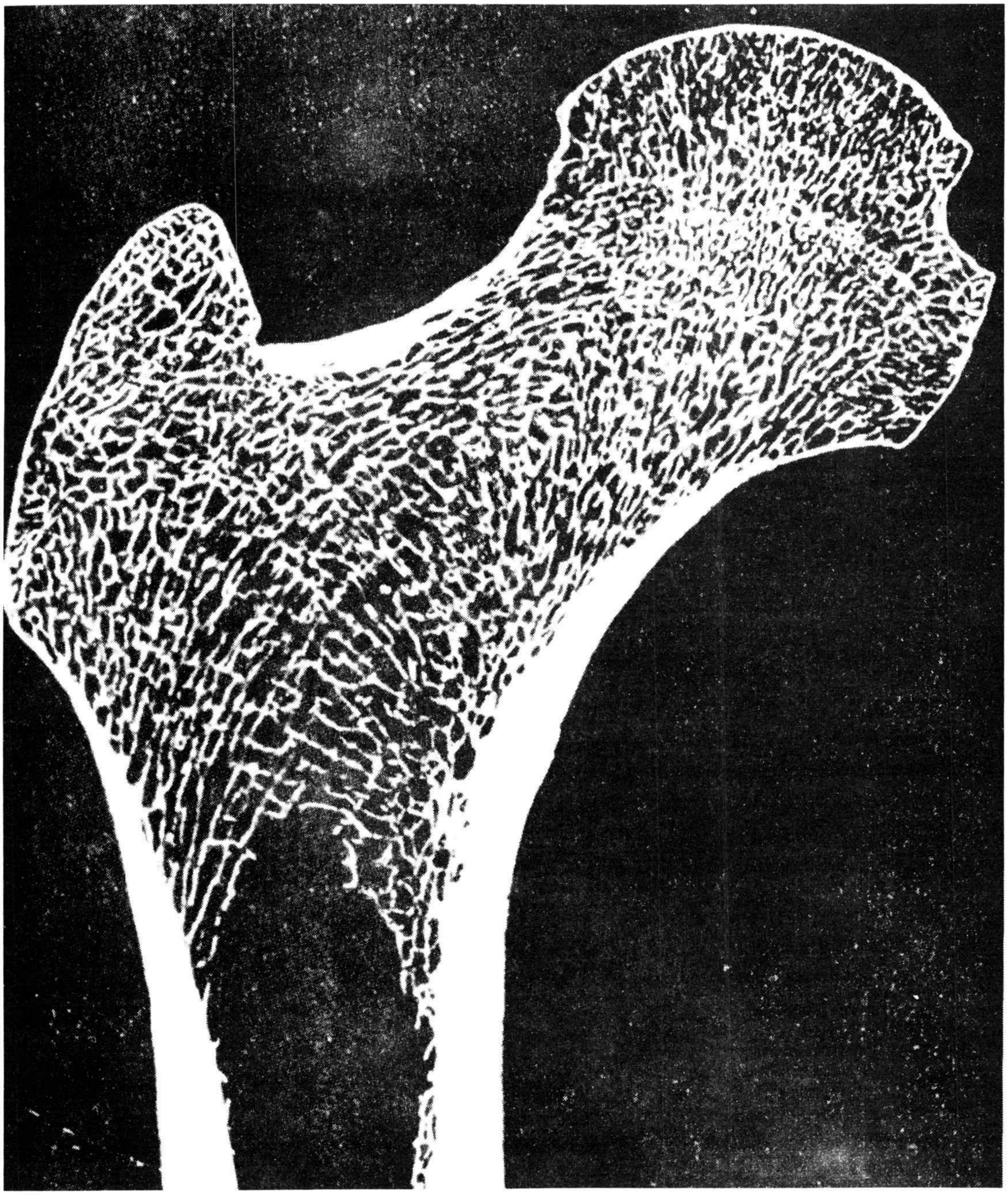

Figure 1. Bone Structure: Cortex (outer surface), Trabeculae (beams), and Marrow Cavity of the Femur.

The cortex (outer surface) is dense and hard and is composed of bony layers packed closely together. The surface within the cortex of flat bones and at the ends of long bones is occupied by trabeculae (beams) of bone. Individually these tiny beams are weak but collectively they form a strong bracing system. The space within the trabeculae and the cavity in the shaft of long bones are filled with marrow where red blood cells are formed (38, 50).

Basic to this research is the understanding that bone is a living tissue. Bone is composed of a tough organic matrix that is greatly strengthened by deposits of calcium salts. The average compact bone contains approximately 35 percent matrix and 65 percent salts. The organic matrix is 95 percent collagenous protein fibers and five percent ground substance. The collagen fibers extend in all directions in bone but primarily along lines of tensional force. The ground substance is composed of extracellular fluid plus mucoprotein containing chondrotin sulfate and hyaluronic acid. The precise function of the ground substance is not known but possibly it helps to provide a medium for deposition of calcium salts (33). Crystalline salts deposited in the bone matrix consist mainly of calcium and phosphorus. Bones contain 99 percent of the body's calcium and 86 percent of the phosphorus. Also, 50 percent of the body's magnesium and 35 percent of the sodium are found in the bones (35, 50, 57).

Bones have great tensile and compressional strength and are constructed in much the same way as reinforced concrete. The collagen of bone is similar to the steel in reinforced concrete giving it tensile strength (resistance to being pulled apart). The calcium salts are similar to the cement, sand and rock of concrete which provide the compressional strength (resistance to being compressed or crumbled) (33, 38).

Throughout the matrix and bone crystals are connecting canals which contain nerves and blood vessels which supply nutrients to the bones. Bone is cellular and is well vascularized. The total blood flow through the bone is estimated to be 200-400 ml/minute (33).

The size and compactness of bony material undergoes change during growth. During infancy, bones are like firm cartilage possessing a low calcium and phosphorus content. They become firmer as these two minerals are deposited in and around the cartilage in a bone-building process called ossification or calcification (7). Because the bones of children have an excess of collagen as compared to mineral matter, they are more easily bent. In contrast, the bones of elderly people become less compact, the calcium salts are reduced, and the bones become brittle and fragile (38).

Importance of Calcium in the Body

Calcium is important in bone formation and is a key structural mineral in human metabolism. Of the total lean body weight, 1.5 to 2 percent is calcium. This amount is greater than that of any other mineral. Ninety-nine percent of the body's calcium is found in the skeleton. The one percent located outside the skeleton is found in the extracellular fluids and soft tissues of the body. This small portion of the total body calcium is involved in several regulatory functions such as blood clotting, excitability of nerves, and muscle contraction and relaxation (7, 84).

Recommended Daily Allownace of Calcium

Calcium is an essential nutrient throughout the entire life cycle. The amount of this mineral needed remains somewhat controversial. Some researchers indicate that at least 1100 mg are needed daily just to maintain zero balance in the adult (28). However, populations in some areas live in "apparent health" while their calcium intake varies greatly (7, 37, 42).

The Food and Nutrition Board of the National Academy of Sciences-National Research Council, determines the amount of each nutrient the diet should furnish during various stages of the life cycle by periodically evaluating the latest research available. The Recommended Daily Allowance (RDA) is an estimate of the daily intake necessary for maintenance of "good nutrition and health" (7). The RDA for calcium and phosphorus as revised in 1974 is shown in Table 1.

The RDA for calcium is well above minimum maintenance levels and provides for a liberal margin of safety so that calcium balance can be maintained. Calcium balance represents the net excess or deficit of retention of the element as compared to intake. The normal condition for a growing child is a substantial positive calcium balance representing the retention necessary for skeletal growth. The body's demand for calcium during growth periods parallels the skeletal needs (50).

The calcium content of the body increases faster in relation to body size the first year of life than at any other time during the life cycle. Growing children need two to four times as much calcium per unit of body weight as adults. However, during childhood (1 to 10 years), retention of dietary calcium is less than during infancy. Children whose diets are deficient in calcium and phosphorus will experience slower calcification of bones and teeth (7). Between the ages of 11 to 19 the RDA increases from 800 mg to 1200 mg daily to facilitate the rapid skeletal growth which commences about age 12 (7).

TABLE 1. Recommended Daily Dietary Allowances for Calcium and Phosphorus. Revised 1974.

	Age	Weight		Height		Calcium	Phosphorus
	(years)	(kg)	(lbs)	(cm)	(in)	(mg)	(mg)
Infants	0.0-0.5	6	14	60	24	360	240
	0.5-1.0	9	20	71	28	540	400
Children	1-3	13	28	86	34	800	800
	4-6	20	44	110	44	800	800
	7-10	30	66	135	54	800	800
Males	11-14	44	97	158	63	1,200	1,200
	15-18	61	134	172	69	1,200	1,200
	19-22	67	147	172	69	800	800
	23-50	70	154	172	69	800	800
	51+	70	154	172	69	800	800
Females	11-14	44	97	155	62	1,200	1,200
	15-18	54	119	162	65	1,200	1,200
	19-22	58	128	162	65	800	800
	23-50	58	128	162	65	800	800
	51+	58	128	162	65	800	800
Pregnant						1,200	1,200
Lactating						1,200	1,200

Even when growth has ceased, bone is constantly being remodeled but at a slower rate. For the adult, the normal condition is zero calcium balance (absorption equals excretion) (50). A large portion of the adult population is usually in negative calcium balance due to insufficient intake (30, 50). There is a misconception that adults outgrow their need for this mineral (7). Also, negative calcium balance may be observed in women during pregnancy or lactation due to the demands of the developing fetus or the calcium secreted in breast milk (7, 50).

Calcium Metabolism

Calcium metabolism is defined as "the total sum of the processes by which calcium enters and leaves the body" (7). How calcium is made available for use by the body is pertinent to this research and considers: calcium absorption, calcium excretion, and blood calcium levels.

Calcium Absorption

Calcium is made available to the body by absorption of ingested calcium from the small intestine (50). According to Guyton (33), calcium is poorly absorbed from the intestine because of the relative insolubility of many of its compounds. McLean (50) indicated that a large part of the ingested calcium passes through the alimentary tract unabsorbed. Of the absorbed calcium, a considerable quantity is secreted back into the intestine combined with the digestive juices. From the standpoint of net absorption, normal adults may utilize as little as 20 percent of the calcium ingested (33). Albanese (7) stated that calcium absorption ranges from 10 to 50 percent of the intake. Several factors, dietary and nondietary, effect calcium absorption across the intestinal wall.

Nondietary Factors Influencing Calcium Absorption. According to West et al. (84), the need for calcium may be a significant factor in absorption. The body can adapt to a certain extent to meet its calcium needs. Decreased calcium intake or an increased demand due to growth, lactation, pregnancy, etc., results in an increased absorption across the intestinal wall. However, the percent of calcium absorbed decreases if the intake is plentiful although the absolute quantity absorbed is greater (7).

According to Albanese (7), calcium absorption decreases during illness which indicates that general health may be a factor in absorption. Smith (72) stated that age is a factor with absorption decreasing with increasing age. Also, physical activity appears to increase calcium absorption while inactivity tends to decrease the absorption of this mineral (37, 72).

Parathyroid hormone (PTH) is concerned mainly with regulation of serum calcium levels. However, this hormone does have some effect on calcium absorption from the intestine by way of vitamin D. A decrease in serum calcium levels is the signal to which the parathyroid gland responds by secreting PTH. PTH enhances calcium absorption by increasing formation of the active form of vitamin D (1,25-dihydroxycholecalciferol). In the absence of vitamin D, the effect of PTH on calcium absorption is minimal (33, 67).

Dietary Influences of Calcium Absorption. Several dietary constituents influence calcium absorption from the intestine including: vitamin D, phosphorus, fat, protein, lactose, fiber, and fluoride.

The most important single factor in the absorption of calcium is vitamin D (50). Two important forms of vitamin D in human nutrition are: 1) ergocalciferol (vitamin D_2) - primarily a synthetic form of vitamin D, and 2) cholecalciferol (vitamin D_3) - the natural vitamin D. Vitamin D itself is not the active substance that actually causes increased calcium absorption. Vitamin D_3 is formed in the skin as a result of irradiation of 7-dehydrocholesterol by ultraviolate rays from the sun. Vitamin D_2 is formed by irradiation of ergosterol. Both of these vitamin D's are altered in the liver to form 25-hydroxycholecalciferol. In the kidneys, PTH stimulates conversion of 25-hydroxycholecalciferol to 1,25-dihydroxycholecalciferol which is the active form of vitamin D. This active form of vitamin D influences formation of calcium-binding protein (CaBP) in the intestinal epithelium which aids calcium absorption (33).

The ratio of calcium to phosphorus in the diet is thought to have an important bearing on calcium absorption. The recommended ratio of these two minerals is between 2:1 and 1:2. However, if the intake of calcium and/or vitamin D are adequate, ratios outside the above do not appear to affect calcium absorption (7, 33, 84).

Under normal circumstances, more or less fat in the diet has little effect on calcium absorption. However, in cases of excessive dietary fat content, calcium absorption may be inhibited. Fatty acids formed but not absorbed in the intestine combine with calcium creating calcium soaps. These calcium soaps are insoluble and, therefore, are not absorbed (84).

High fiber diets may also inhibit calcium absorption by forming insoluble calcium salts which are excreted in the feces (7). Some calcium salts are much more soluble in a solution of amino acids than in water. Therefore, calcium absorption may be enhanced with increased protein consumption (84). However, Albanese (7) indicated that a high dietary protein intake has been shown to increase urinary calcium excretion.

Ingestion of the disaccharide lactose (of milk origin) has been shown to improve calcium absorption by increasing the permeability of the small intestinal absorptive cells. Also, fluoride, a trace element, has been shown to promote calcium absorption (7).

Calcium Excretion

Loss of calcium from the body takes place mainly through two channels: the alimentary canal and the urinary tract (50). Calcium excretion in the feces is equal to the difference between ingested calcium and calcium absorption. Guyton (33) indicated that seven-eighths of the ingested calcium is excreted in the feces daily and that only one-eighth is absorbed. Albanese (7) stated that fecal calcium ranges from 140 to 180 mg daily but varies with calcium intake. Calcium excretion in the urine is regulated mainly by PTH. When calcium concentration of the extracellular fluid is low, calcium excretion by the kidneys is low (33). Also, a small amount of calcium (15-20 mg/daily) is lost from the body in sweat (7).

Blood Calcium Levels

The function of the small amount of calcium found in the extracellular fluid necessitates the concentration being held relatively constant. The concentration of this mineral in the plasma is approximately 10 mg percent, normally varying between 9.2 and 10.4 mg percent. Elevation or depletion of calcium ion concentration in the extracellular fluid causes extreme immediate effects. When the extracellular fluid concentration falls below normal (hypocalcemia), the nervous system becomes "progressively more and more excitable" because of increased neuronal membrane permeability in the central nervous system and the peripheral nerves. The nerve fibers begin to discharge spontaneously initiating nerve impulses to the skeletal muscles which produce contractions (tetany). Also, extreme hypocalcemia greatly decreases bone mineralization (33). Conversely, if levels of calcium in the body fluids rise above normal (hypercalcemia), the nervous system is depressed with a contrasting effect (33).

Plasma calcium concentration is regulated mainly by PTH within the narrow limits indicated (33, 50). A very small decrease in calcium (1 percent) in the extracellular fluid will cause a 100 percent increase in secretion of PTH and will also cause hypertrophy of the parathyroid glands. For example, these glands become greatly enlarged during pregnancy and lactation. PTH causes a marked elevation in calcium and a decrease in phosphorus concentration (33, 50).

PTH mobilizes calcium from several sources to raise serum calcium levels: 1) The increase is caused principally by rapid absorption of calcium from bones. The skeletal system contains such a high degree of calcium compared to extracellular fluid that it is impossible to discern any immediate effect on bones. The prolonged effect, however, is evident resorption of all bones (33, 50). 2) PTH causes increased renal tubular reabsorption of calcium. If PTH did not cause reabsorption of calcium by the kidneys, bones would eventually become depleted of this mineral (33, 50, 67). 3) PTH also mobilizes calcium by stimulating formation of the active form of vitamin D which enhances absorption across the intestinal wall (33).

Anything that brings about an increase in serum calcium ion concentration causes reduced activity in the parathyroid gland and a decrease in its size. Factors which would bring about this increased concentration are: 1) excessive amounts of calcium and/or vitamin D in the diet, 2) bone resorption caused by factors other than PTH such as physical inactivity (50).

PTH is also important in phosphate metabolism. The normal serum ratio of calcium to phosphorus is about 2.5:1. PTH acts to keep this balance in line by increasing urinary excretion of phosphorus when calcium drops below normal or when dietary intake of phosphorus is elevated (7, 33).

When plasma calcium levels return to normal, calcitonin is secreted by the thyroid gland which inhibits PTH effect (33, 35, 57).

Bone Remodeling

Throughout life bone is continually being remodeled so that some new bone is always being formed. More than 90 percent of the material of bone is extracellular. Remodeling of this material, on a microscopic scale, resembles the remodeling of a building. The destructive process (resorption) is carried out by osteoclasts and the reparative process (accretion) by osteoblasts (37). New osteoclasts and osteoblasts are being formed constantly. However, certain stimuli, such as PTH, can drastically change the rate of formation.

These cells are almost always formed in the following sequence: 1) mesenchymal stem cells give rise to osteoclasts, 2) osteoclasts give rise to osteoblasts, and 3) osteoblasts give rise to osteocytes. Mesenchymal stem cells are located in bone marrow and periostium where they form osteoclasts. Osteoclasts persist for a few hours to many days depending on the stimuli. They are then converted to the osteoblastic stage whose length is also determined by other stimuli. As osteoblasts form new bone, they become entrapped in this new bone to form osteocytes (bone cells) (30,33,37).

Skeletal remodeling is related to structure and homeostasis. Bone remodeling is physiologically important for four reasons. The first three reasons are structural. First, bone ordinarily adjusts its strength in response to stress placed on it. Bone is deposited in proportion to the compressional load that it must carry. For example, bones of athletes are heavier than those of nonathletes. Also, research has shown that in a person who has one leg casted but continues to walk on the opposite leg, the bone of the casted leg becomes thin and decalcified while the opposite bone remains thick and normally calcified. Therefore, continual physical stress stimulates osteoblastic deposition of bone (33, 37). Second, under certain circumstances bone stress can change the shape of bones for proper support of mechanical forces by deposition and resorption. For example, if a long bone in the leg is broken and then heals at an angle, the compressional stress on the inside of the angle causes increased deposition of bone while increased resorption occurs on the outer side of the angle where bone is not compressed. After several years of increased deposition on the inner side of the angulated bone and resorption on the outer side, the bone becomes almost straight. This is especially true in children when bone remodeling is rapid (29). Third, this process helps maintain normal bone toughness. Remodeling renews the aging bony material and hence maintains the properties of the bony members in a condition optimal for their structural purposes. Because old bones become relatively weak and brittle, new organic matrix is needed as the old matrix degenerates. Bones of children show little brittleness when rates of absorption and deposition are high as compared to adults when these rates have slowed (33, 37). The fourth important reason for bone remodeling is homeostatic. Bone resorption pours calcium into the blood and is the primary means whereby the organism draws on its skeletal calcium reserves. On the converse side, mineralization of newly formed bone takes calcium out of the blood. This process constitutes the largest single demand to which the calcium homeostatic system must respond (37).

Osteoporosis

Osteoporosis is a major bone mineral disorder that represents irregularities in bone remodeling, either of its control which is the balance between the destructive and reparative phase, or of the various steps or processes involved in these activities (37). An equal balance between bone accretion and resorption appears to be maintained in the young so bone mass remains constant. However, during the third decade for women and the fifth for men, bone equilibrium is lost with bone resorption becoming greater than bone accretion. This resorption imbalance results in progressive bone loss of 24 to 30 percent in women and 10 to 15 percent in men by the seventh decade (72).

The physiologic atrophy of the bone tissue in old age (osteoporosis) in no way differs from the atrophy of disuse.

Atrophy of bone is unlike atrophy of soft-tissue structures such as muscle or liver. In soft tissues atrophy produces a reduction in the size as well as the number of cells and results in shrinkage of the external dimensions of the whole organ. Atrophy of bone occurs without a corresponding change in the volume or external dimensions of the bone, but the mass of bone tissue is reduced. In a cross section, the cortex is thin, and the individual trabeculae are also thin and widely separated (50).

Due to the decreased mass and increased cell death, osteoporotic bone is weaker than normal bone. This results in an increased probability of fracture and poses a significant hazard to the aged. In fact, the condition is generally discovered by fracture either after a trivial injury or no actual injury at all (50). Beals (14) reported on the mortality of 607 aged patients treated for hip fracture from 1966 to 1971. He observed a hospital mortality of 12.5 percent and a 50 percent mortality after one year.

The projected increase in the population of 64 years of age and over can be expected to lead to a greater incidence of osteoporosis and fractures. "In short, bone health is becoming a major health problem in the United States" (5).

Age and Sex

Age

Osteoporosis, a universal decrease of bone mass frequently considered to be synonymous with bone aging, occurs extensively in elderly subjects (57). The knowledge that fractures in the aged are attributable to a loss of bone strength has been known for a long time, and certainly since 1824. It is only recently, however, that good epidemiological data have become available to show the precise relationship between age and fracture rate (5).

Surveys by Iskrant (41), Nordin (52), and Trotter (78), showed that virtually the entire aging female population is affected by postmenopausal osteoporosis losing as much as 20 to 60 percent of bone mineral content over the 50 to 80 plus age span. The same condition is found in five to ten percent of men. In his survey, Trotter (78), determined the weight/volume ratio of young and old, male and female, white and black skeletons and reported a definite decrease in bone density between youth and old age. The loss was greater in females than in males and slightly more in whites than in blacks.

Surveys taken in homes for the aged and of ambulatory individuals aged 45 to 95 years requiring rehabilitative care have disclosed an incidence of bone loss ranging from 15 to 50 percent. Other estimates indicated that at least ten percent of the population over 50 years of age have osteoporosis severe enough to cause vertebral, hip or long-bone fractures. Of the approximately 6,000,000 spontaneous fractures due to osteoporosis which occur annually in the United States, about 5,000,000 are sustained by postmenopausal women (8).

In many instances, advanced osteoporosis is first revealed by the occurrence of spontaneous fractures of the hip, spine or long bones. In postmenopausal women, the first symptom is progressive and persistent pain in the lumbar spine which seldom radiates. The progressive decrease in vertebral bone mass results in a gradual loss of height and eventual kyphosis (Dowager's Hump) in the years following menopause. These changes constitute late overt physical evidence of advanced osteoporosis (8, 68).

Sex

All people appear to lose bone as they age, but the age at which this loss begins and the rate at which it occurs seems to be sex-dependent (3). The bone density of young males and females (age 5-15 years) was approximately the same. After age 15, however, the density became significantly greater in the males than in the females. In females, bone density reaches a peak at age 35-45 years and then declines progressively as age advances. In males, the peak is reached at age 45-55 years and the decline starts at age

55-65 years. The rate of decline per decade is about ten percent of the initial mean value in women and somewhat less in men. In a ten-year research study which included some 4,000 free-living participants, Albanese (6) concluded that significant subnormal bone density prevails in 10 to 15 percent of healthy normal individuals in both sexes as early as age 25. He also found that the bone density of 17 black females included in his survey was 15 to 20 percent higher than white females and equal to that of some white males of similar age. These results support the findings of Trotter (78) in regard to bone density in blacks and whites.

Several reasons have been purported as to why the difference exists between men and women: 1) weight-reducing diets which induce not only loss of soft tissue but also of skeletal mass; 2) calcium loss incurred during pregnancies which may not have been adequately repleted by prescribed prenatal supplements; 3) progressive bone loss associated with hormonal changes of the menopause; and 4) difference in muscular weight and size and the influence that this factor has on the development of bone density (5, 26).

Rarick and Thompson (61) raised the question as to whether the difference in bone mass may be attributed to basic sex differences in physiological functions or to differences brought about by exercise regimes of the sexes. The latter would perhaps logically account for much of the difference because of the distinctive role assumed by each sex in our culture. For example, strength and power are believed to be male attributes and are more sought after by boys than girls even at the earlier ages. This concept would support the findings of Albanese (3) that until about age 15, bone density in males and females is approximately the same.

Hormonal Influences in Bone Aging

Hormonal influences, such as estrogen deficiency in females, increased or persistent parathyroid hormone action, and decreased calcitonin action, might be intimately related to bone aging (57).

Parathyroid hormone. Bone aging appears to be associated with increased susceptibility to PTH - the major bone resorbing hormone (57). In a research study by Hossaian et al. (39), greater metacarpal cortical thickness was found in patients with hypoparathyroidism than in those with hyperparathyroidism. Evidence indicates a decreased capacity with age of the kidneys to metabolize PTH. This phenomenon would increase the biological activity of PTH in the organism (57).

Calcitonin. Calcitonin, a hormone secreted from the thyroid gland, is known to inhibit bone resorption and counteract the action of PTH at the bone level. While no significant change of calcitonin secretion has been demonstrated with advance in age, a definite decrease in the effect of this hormone in aged animals has been repeatedly established. Increased susceptibility of the aging bone to resorption might thus be explained in part by the imbalance in sensitivity to these two hormones. The relative predominance of PTH effect over calcitonin might, therefore, increase susceptibility of the aging bone to osteoporosis (57).

Estrogen. Osteoporosis is several times more common in females than males after age 45-50. In view of this definite sex-dependence in the development of osteoporosis, the effect of estrogen withdrawal appears to be important.

In order to study the effect of estrogen on bone aging and osteoporosis, right hind limbs of rats were immobilized through application of plaster cast in intact and ovariectomized rats. Ovariectomy appeared to facilitate the development of immobilization osteoporosis. Also, ovariectomy facilitated the development of osteoporosis in response to daily administration of parathyroid extract. On the other hand, injections of estrogen given to some rats appeared to prevent the development of osteoporosis (55).

Research indicated that patients with postmenopausal osteoporosis had higher serum PTH levels than subjects of corresponding age without osteoporosis. Estrogen appears to protect the bone from the effect of PTH. Estrogen withdrawal, therefore, leaves the bone unprotected and more susceptible to the calcium resorption influence of PTH (57).

Nutrition

Bone density reflects both age and diet. There is a high statistical correlation in the United States between the incidence of subnormal bone density, increased fracture rate and low calcium consumption (7).

The amount of calcium stored in bones prior to the onset of rapid skeletal growth appears to be important in determining the nutritional end point attained at maturity. An adequate intake of foods supplying calcium may offer protection against bone disorders in later years. Unfortunately, inadequate calcium intake is one of the nation's primary nutritional concerns. For example, girls from age nine to 14 are, on the average, receiving about 25 percent less calcium than recommended (7).

If adequate calcium is not available, not absorbed from the diet, or if excessive amounts are lost from the body, it must be provided by the skeleton to maintain serum calcium at a normal level (42). When nutritional disturbances in young animals become so severe that nutrients are inadequate to supply all the needs of the body, preference is given to those organs on which continued existence depends. In a crisis, bones cease to grow. They proceed to grow again, however, when the crisis is over. The ability of such animals to grow after the period of undernutrition is over is limited, and the animals fail to achieve the full stature of their normally-raised littermates (46, 58).

The increase in patient visits for the treatment of osteoporosis, with or without fracture, coincides with the extremely inadequate dietary calcium intake in the population of the United States. The Recommended Daily Allowance (RDA), for calcium is 800 mg/day. Approximately 30.5 percent of the entire American public consumes less than the RDA (25). In a study involving 237 female patients, those consuming less than the RDA of calcium daily had almost 25 percent less in mean ash content of wet bone than females consuming 800 mg of calcium or more daily (40). Some investigators maintain, however, that normal daily loss of calcium is actually closer to 1100 mg, thus requiring an increase of 35 percent in the RDA factor just to achieve calcium balance (28).

While it is clear that osteoporosis does have a nutritional component, it cannot be described solely as a calcium-deficiency disease as dietary calcium deficiency has not been universally related to osteoporosis. Symptoms of osteoporosis may occur with adequate levels of calcium intake or may be absent with low calcium intake. This phenomenon may be due in part to differences in calcium absorption across the intestinal wall (37). Another reason may be that a dietary history reflects the current dietary status of an individual while the "bone is a mirror of the dietary habits of a lifetime" (42). Also, vitamin D is necessary for normal calcium absorption from the intestine. In fact, some researchers claim it is the single most important substance regulating the intestinal absorption of calcium (11, 52). Vitamin D deficiency is rare in the United States but may occur in populations not getting adequate sunshine such as geriatric, immobilized, or chronically hospitalized patients (79).

Dietary Sources of Calcium

Dairy products are the most important source of calcium, milk and cheese being the richest sources. Whole milk contains 115 mg percent while cheese products vary from less than this amount to as much as 1100 mg percent. Grains are low in calcium (white flour - 20 mg percent; whole wheat flour - 40 mg percent). Meats are a poor source of calcium containing only between 10-20 mg percent. Seafoods are a better source, especially canned fish because the bones are still present. Canned salmon contains 300-400 mg percent. Vegetables are not an outstanding source although green tops, such as turnips, are rich in calcium (84).

A daily intake of 800-1000 mg of calcium is necessary to maintain "normal or optimal bone health." To achieve this goal, it would be necessary to consume one quart of milk per day or an equivalent in cheese products (7). In a group of 87 osteoporotic patients, only one in three drank milk. Because milk is vitamin D enriched, deficiency of this vitamin may also be a factor in such a group (42).

Effects of Calcium Supplements on Osteoporosis

Research indicates that dietary supplements of calcium and/or vitamin D will increase bone density. Albanese (8) conducted a study involving female nursing home residents between the ages of 69 and 80. Their normal diet contained approximately 400 mg of calcium per day, and with a supplement, supplied a daily total of approximately 1000 mg. A control group residing in the same home did not receive the supplement and continued receiving 400 mg from their daily diet. Even though they were three years older than when they started taking the additional calcium, the bone density of the women taking the supplement was 12 percent higher than the control group. These results suggest that under conditions of low calcium intake due to inadequate consumption of dairy products, bone loss in the elderly may be decelerated or reversed by taking calcium supplements.

Physical Activity

Osteoporosis appears to be a form of disuse atrophy of the skeletal tissue. It has been established that the growth of bone is dependent, to some extent at least, upon the amount of stress and strain exerted upon the bone (64). As early as 1907, R. Thoma (76) held an extreme mechanical view that all bone formation, including the first bone formed in the embryo, takes place as a response to the action of stress and strain. According to Wolff (87), bone adapts to stress:

> Every change in the form and the function of bones or of their function alone, is followed by certain definite changes in their internal architecture, and equally definite secondary alterations in their external conformation.

Thus, bone is highly sensitive to alterations of its normal mechanical functions. Disuse is followed by atrophy (loss of bone substance), and increased use is accompanied by hypertrophy (increased bone substance) (32).

Gravity, Muscular Contraction and Bone

The two main external forces acting on bone are gravity and muscular contraction. The effects of the presence or absence of gravitational and/or muscular stress on bone has been an object of study by numerous researchers (72).

Klein evaluated elementary and junior high age boys for lateral asymmeteries of the pelvis and legs. Lateral pelvic imbalance due to short leg syndrome was corrected by using a heel lift on the shoe of the short leg to achieve pelvic symmetry. After six months a significant improvement was found following removal of the heel lift. It was determined that the increased stress imposed by the heel lift had been a stimulus to growth in the short extremity (43).

Hypogravity space travel has demonstrated the importance of gravity and muscle contraction on bone homeostasis. Mack (48) demonstrated small, but significant, bone mineral loss in astronauts participating in the Gemini space flights. The astronauts of the 14-day Gemini VII flight demonstrated less bone loss than the astronauts of earlier flights. The reasons given for this reduced bone mineral loss were greater food consumption and participation in an on-board isometric and isotonic exercise program.

Immobilization and Bone

Evidence obtained from subjects who have become bedfast gives some insight into the role which physical activity plays in maintaining the normal structure of bone tissue. Asher (10) in pointing out the dangers of prolonged bed rest, stated that bones which are not subjected to normal use lose calcium and that the absence of weight-bearing may delay the complete union of fractured bones.

The investigation of Campbell (18) demonstrated that when immobilized, tissue protein losses in young men were associated with marked increase in urinary calcium output which is an indication of bone loss.

Albanese (6) observed protein losses equivalent to 1.5 to 2.0 pounds of muscle tissue per week in stroke patients whose mobility was limited by paralysis. However, they found by programmed exercise and ambulation, protein depletion could be reduced at least in part and sometimes completely.

Chalmers (19) attributed decrease in bone density of a fractured leg to lack of activity. Heaney's (37) research also indicated that inactivity will result in decreased bone mass due to the great increase in bone resorption. In the acute stage of osteoporosis, there is also a gross depression of the efficiency of gastrointestinal calcium absorption; thus, absence of muscular activity does result in a decrease in bone density.

Muscle Size and Bone

In his comparison of 46 necropsies, Doyle (26) found that when matched for body weight, age, and height, the weight of the third lumbar vertebrae was directly correlated with the weight of the psoas muscle. This finding led him to propose the following hypothesis: "The weight of a muscle reflects the forces that it exerts on bones to which it is attached and a reduction or increase in muscle weight results in a corresponding loss or increase in bone." Verification of this hypothesis would shed light on a number of unexplained observations. The higher incidence of osteoporosis in women compared with men (when size is taken into account), and in white populations compared with black populations may depend in part on quantitative differences in muscle. Also, some of the bone loss that occurs after the age of 50 in men and women may be due to loss of muscle weight.

Growth Hormone and Bone

During growth, the human growth hormone (HGH) stimulates growth of long bones. However, when the epiphyses of long bones have united with the shafts, the bones can no longer increase in length, but they can continue to increase in thickness (33).

For many years it was believed that HGH disappeared from the blood when growth ceased. It has now been proven that HGH secretion continues after adolescence. The rate of HGH secretion in the adult is increased during moderate exercise (33). Research by Sidney and Shephard (71) indicated that elderly subjects show an increase in release of HGH in response to submaximal effort after nine to ten weeks of endurance training. Szanto's (75) research concurred with Sidney and Shephard that HGH secretion is enhanced by exercise.

Harper (34) stated that HGH increases intestinal absorption of calcium and also increases retention of calcium by the bones. The fact that plasma HGH concentration increases in response to exercise and that it enhances calcium retention by the bones would indicate that exercise could indeed increase the density of bones (35, 37).

Physical Activity and Bone (Cross Sectional Studies)

An investigation by Adams (1) in which 100 black women, 17 to 21 years of age, who had undergone a lifetime of hard manual labor were compared on the basis of several anthropometric measures with 100 young women of similar age who had engaged in no heavy manual labor. The findings showed that the women who had engaged in heavy labor from early childhood were taller and heavier at the conclusion of the growing years than the nonworking women. The hard-working women labored regularly 10 to 12 hours daily on southern plantations and came from a lower socioeconomic group than the nonworking blacks. These factors led the author to conclude that the differential factor was the regime of heavy exercise rather than nutritional differences which would presumably have favored the nonworking women.

Emiola and O'Shea (27) compared bone density of 90 male and female college students between the ages of 20 and 25 which were divided into three physical activity levels. The results of the study revealed a significant difference in bone density between the physical activity levels. The highly active group had denser bones than the moderate and low activity groups.

Dalen (23) found that cross country runners between the ages of 50 and 59 had significantly greater bone mineral content (25 percent) in both the femur and the humerus when compared to a control group of the same age, weight, and height.

Physical Activity and Bone (Longitudinal Studies)

Research indicates that lack of physical activity definitely is one of the principle causes of osteoporosis. However, there is a lack of longitudinal research available where human subjects have been placed on exercise regimes to determine the effect of this treatment on osteoporosis. The few studies that have been done appear to have positive results. Hattner and McMillan (36) suggest that the most useful therapy in disuse osteoporosis could be simple weight bearing or exercises designed to simulate weight bearing. In patients with idiopathic osteoporosis, bone formation appeared to increase with physical therapy. Also, positive results were observed in patients with disuse atrophy of the skeleton (15). As was mentioned earlier, Albanese (6), demonstrated that exercise and ambulation could reduce protein depletion at least in part and sometimes completely in stroke patients experiencing some paralysis.

Smith (72) studied changes of bone mineral content due to exercise in residents of a nursing home over a period of three years. The bone mineral of the exercise group showed a significant increase of 2.29 percent while the control group lost an average of 3.28 percent. This study demonstrated that physical activity does play an important role in maintaining and increasing bone mineral content in the aged. Physical activity as a stimulus clearly produced bone mineral accretion in the elderly as the result of increased stress and strain on the living bone tissue.

Bone hypertrophy appears to be directly related to physical activity and weight bearing, but the way in which exercise triggers the growth mechanism is not known. There seems to be little doubt, however, that stress in the form of mechanical tension precipitates a chain of phenomena which results in both physical and chemical changes in muscle and bone tissue (9). Therefore, it does appear possible to increase the bone mineral content above "normal" in adults by physical activity; on the other hand, inactivity will result in bone loss.

Methods of Bone Density Measurements

Due to the increase in the incidence of ostoeporosis and other factors that affect skeletal mass, such as weightlessness, immobilization, and inactivity, much interest has been generated in the study of bone densitometry. Five commonly used methods are: calcium content or ash weight, sonic measurement, iodine-125, metabolic balance, and quantitative radiographic densitometry.

Calcium Content or Ash Weight Method

The calcium content or ash weight is one of the earliest methods used in the study of bone. This method is a destructive technique and, therefore, is not practical for use in measuring skeletal changes in living humans. In this method, animals are sacrificed and the bone to be used is removed and measured for length. Needed sections of the bone are weighed wet after the marrow is removed. The sections are then ashed and analyzed for calcium content (24).

Sonic Measurement Method

The sonic method uses sound velocity. This method is based on the principle that the velocity of sound varies according to the density of the medium through which it passes. The velocity is greater in a solid than a liquid medium. The transit time is used to measure the amount of bone present. Transmission time through a bone chip of known composition can be used to compare the difference between transmission time through bone and soft tissue and soft tissue alone. Thus, when the dimensions of a bone are determined from an x-ray, the density can be estimated (20, 65).

The sonic method usually gives a value which results in too high a prediction of the mass of calcium present and, therefore, is not effective in detecting osteoporosis especially in the earlier stages (20).

Iodine-125 Method

Strandjord and Lanzl (74) developed an instrument using radioactive I^{125} for nondestructive testing of bone mineral in the skeleton. The transmission through a single finger bone of the radiation eminating from I^{125} is observed. A higher transmission of radiation will occur through a bone with a lower mineral content. Decreased bone mineral content can be due to: 1) a bone of lower density, 2) a thinner bone, or 3) a combination of 1 and 2. Therefore, this method may not be reliable due to variance of "healthy" bone (4).

Metabolic Balance Method

Metabolic balance has been one of the principal methods used for measuring skeletal changes in human beings. This method employs the assessment of urinary excretion of calcium as a measure of bone loss but only "sheds light" on a portion of the total biochemical condition (85). Research studies by Albanese et al. (4), and Reshef et al. (62) established that urinary calcium excretion does not always correlate with the presence of radiologically diagnosed osteoporosis.

Quantitative Radiographic Densitometry Method

Quantitative radiographic densitometry is a nondestructive method for the measurement of bone density. This method has been thoroughly investigated as a method of accurate assessment of bone mineral content and will be used in this study (63).

In 1949, Brown developed a bone density computing machine which enhanced the analysis of information from suitably exposed and standardized x-rays. Building on the work of Brown, Schraer (66) developed a densitometer which analyzed x-rays for density of bone. A specially designed standardized aluminum alloy wedge is simultaneously exposed with the bone to be evaluated. The film is then carefully developed and analyzed in the densitometer. This method has been validated by the studies of Baker and Schraer (12) in 1958 and Schraer et al. (66) in 1959.

Following the experience of Schraer and his associates, in 1969 Albanese (3) reported an improved quantitative radiographic survey technique. Albanese (4) conducted additional research in 1972 to further validate this new technique.

While diagnosis of osteoporosis is made without difficulty at the full stage of its development, detection at an earlier stage or evaluation of the course of the disease has been rather difficult (57). Many of the methods to date do not appear to be readily adaptable to the ambulatory subject as hospitalization or confinement is required. Because of the limitations of the various procedures for detecting bone loss, osteoporosis continues to be a syndrome of unidentified pathogenesis and etiology (3, 50).

The development of quantitative radiography, however, allows for the detection of bone density changes with greater precision and accuracy. Albanese et al. (3) reported a linear correlation between bone weight, residual calcium content, and radiographically determined density of chicken bones. As density decreased, so did milligrams of calcium in the bone. Also, the loss of trabecular bone can be detected only by changes in the absorption of x-rays or other radiation of the bone (53). These circumstances leave x-ray (radiographic) densitometry as the most practical procedure for survey purposes (3).

Site of Measurement

Research has indicated that the density of several skeletal sites are representative of the density of the total skeleton (13, 81). The spine has long been considered the densitometric area of choice; however, there are major technical problems that hinder vertebral densitometry. The complexities resulting from the effects of the superimposed large and variable amounts of surrounding soft tissue and the nonuniform bowel contents on the bone image present problems in accurate densitometric interpretation of x-rays. Good correlation of the mineral content of the bones of the hand with that of the rest of the skeleton has been demonstrated (80). Schraer (65) and Mack (47) established that radiographic density of the middle phalanx of the fifth digit (phalanx 5-2) serves as a practical and useful criterion of incipient bone loss or overt osteoporosis.

Phalanx 5-2 represents a bone which contains a substantial amount of compact skeletal tissue and is easily accessible for radiographing. For these reasons, this anatomical site was selected for evaluation. Because bone mass values of all phalanges in the same subject are closely correlated, the selection of a single phalanx in the fifth digit was made (47, 65). Recent comparative analysis has demonstrated valid correlation between vertebral radiographically diagnosed osteoporosis and phalanx 5-2 bone loss densitometric measurements. Based on information to date, Albanese et al. (4) suggest that next to vertebral densitometry, the "sites of choice" are phalanx 5-2, the 3 cm site of the radius, the olecranon, and the calcaneus.

Summary

The research indicates that lack of physical activity will cause a decrease in bone density. However, physical activity is not indicated as a treatment to reduce or help control the incidence of osteoporosis. The social, medical and economic implications of providing preventive therapy for an ever-increasing number of osteoporotic patients are enormous and must be measured against the possible side effects of any long-term treatment.

Estrogen replacement appears to prevent bone loss in postmenopausal women and "may" modestly increase bone mass if treatment has been delayed for several years after the onset of menopause. However, when estrogen treatment is discontinued, bone loss is quite rapid. Also, there is some debate as to how long estrogen treatment should be continued due to reports of increased incidence of endometrial carcinoma in estrogen-treated patients (2, 11, 77).

Calcium supplements appear to increase bone density in adults, and there does not seem to be the same rapid decrease in bone mass with discontinued calcium treatment as with estrogen treatment. However, some research indicates a 10 to 20 percent increase in the incidence of renal stones when prolonged calcium supplements are taken (2, 77).

The research to date on healthy college-age subjects indicates that physical exercise may positively affect bone density. Longitudinal bone density investigations have been conducted using female nursing home residents. There are, however, no published studies available involving exercise on male or female subjects between the ages of 35 and 55 years. There is a critical necessity to conduct research to determine if a program of exercise therapy will reverse or retard the adverse effect of factors such as "aging", sedentary living, and poor diet on bone density in this age group.

CHAPTER III

METHODS AND PROCEDURES

The primary purpose of this investigation was to determine if a regular prescribed physical activity (jogging) program could significantly effect bone density in cardiac-prone subjects participating in the Adult Fitness Program at the University of Wisconsin-LaCrosse. The secondary purpose was to determine if there was a significant difference in alterations in bone density due to physical exercise when sex was considered.

Subjects

Seven male and five female cardiac-prone individuals enrolled in the Adult Fitness Program at the University of Wisconsin-LaCrosse served as subjects in this investigation. Subjects were novice participants in the program and were selected based on their availability, willingness and involvement in a structured physical fitness program. A thorough explanation of the scope of the study and testing procedures was presented to each subject before they volunteered. Several potential subjects declined involvement after becoming aware of the x-ray procedure. Also, ten subjects dropped out of the program due to circumstances beyond their control (i.e., two moved, one suffered a broken foot).

The stated purpose of the University of Wisconsin-LaCrosse Adult Fitness Program is to provide an opportunity for area residents to improve their physical and mental well-being via a prescribed exercise program (44). More specifically, the program serves as a health maintenance program emphasizing cardiovascular endurance, strength and flexibility. The program is designed for cardiac prone individuals who are not cardiac patients. A referral from each participant's personal physician is required for admittance to the program.

The LaCrosse Adult Fitness Program is recognized by cardiologists nation-wide as one of the outstanding programs of its kind in the country. Prior to beginning an exercise program, participants undergo a laboratory evaluation which includes the following: height/weight, percent body fat, graded exercise test (GXT), and nutritional analysis (45). Participants are closely monitored each exercise session for pre- and post-exercise heart rate and body weight. Other variables such as duration and intensity of exercise are also closely monitored and recorded. The exercise prescription for each participant is based on age-adjusted maximum heart rate and the results of the laboratory evaluation. The amount of exercise is progressively increased. The progression is based on accumulated monthly exercise data plus results of periodic stress testing. A three-month progress report is forwarded to each participant and physician. (Appendix A).

Test Design

All subjects were volunteer participants entering the Adult Fitness Program at the University of Wisconsin-LaCrosse. The testing procedure for the reference criterion in this study was the radiographic bone density measurement of phalanx 5-2. The subjects were pre-tested, placed on a physical activity (jogging) program, and tested again nine months and 12 months thereafter.

TABLE 2. Design Matrix: Number of Males and Females.

Subjects	Bone Density Measurements				
	Pre-Test	Treatment (9 months)	9-month test	Treatment (12 months)	12-month test
Males	n=7		n=7		n=7
Females	n=5		n=5		n=5

Testing Procedures

Bone Density Measurement

The quantitative radiographic technique for bone density assessment described by Albanese and co-workers (3) was used in this study. This technique is a radiographic measurement of the second phalangeal segment of the small finger (referred to as phalanx 5-2), of the right and left hand of each subject. The technique and site of measurement selected have been found to be the most practical procedures for survey purposes. There is no known adverse effect of the exposure of this small part of a finger to a dental x-ray machine (4, 12, 65).

Physical Activity Inventory

A physical activity inventory was completed by each subject indicating their past and present regular physical activities with the intensity and frequency of each activity. In addition, women indicated whether they were pre- or postmenopausal or if they had had a hysterectomy. (Appendix B).

Nutritional Analysis

Each subject completed a dietary information questionnaire in consultation with a dietitian. During this interview, subjects were asked to record their "normal" twenty-four hour eating and drinking habits. From the information obtained in this interview, a general dietary summary was obtained through use of a computer analysis. The summary specifies protein, fat, carbohydrate, alcohol, vitamin, and mineral content of the diet. (Appendix C). During the study, three additional days were randomly selected in which the subjects recorded their actual food and drink consumption for a twenty-four hour period. The nutritional survey served to indicate if there had been any change in basic eating habits during the course of the study. (Appendix C).

Apparatus and Equipment

Apparatus and equipment used to obtain the criterion measures included:

X-ray Machine. A conventional dental x-ray machine was used operating at 65 kilovolts and 10 ma. The exposures were made at a distance of 11 inches from the cone collar to the subject's phalanx. Exposure time was 0.4 seconds.

Aluminum Wedge and Plate Holder. The wedge consists of eight steps with increments of 20 thousandths of an inch (0.55 mm) each and is machine tooled from 6061 aluminum alloy with a tolerance of one thousandth of an inch. (Figure 2, page 52).

Film. Radiatized dental films (1 1/4 x 1 5/8", Kodak Company, #DF-7) were used. Each film was placed in the slot below the aluminum wedge steps and fitted below phalanx 5-2 on the lucite part of the holder. (Figure 3, pg. 55).

Densitometric Apparatus. The densitometric apparatus at the Burke Rehabilitation Center, White Plains, New York, was used for the scanning of the films.

X-ray Procedure

The subject's little finger was placed on the aluminum wedge holder flush with the steps. An x-ray was taken of the second phalangeal segment (referred to as phalanx 5-2) of the right and left hand. (Figures 2, 3, 4, pg. 55).

All x-rays were taken by the investigator in the Human Performance Laboratory at the University of Wisconsin-LaCrosse. Films were sent to the Burke Rehabilitation Center's laboratory (New York) for processing and photo-

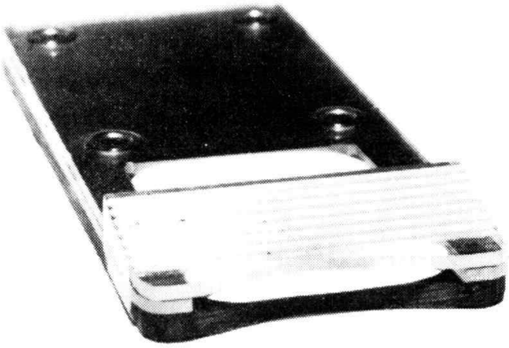

Figure 2. Aluminum Wedge and X-ray Film Holder.

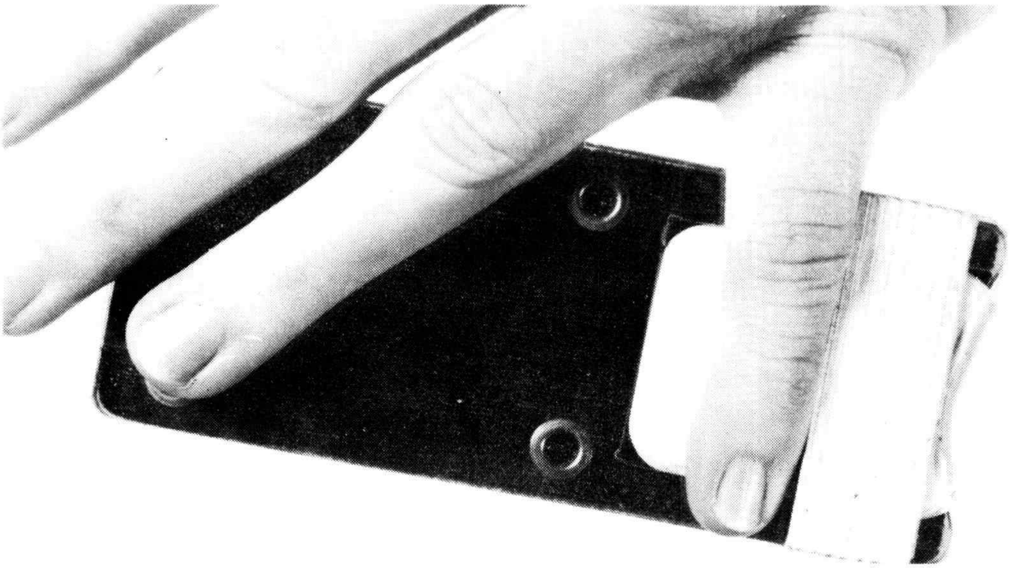

Figure 3. Placement of Phalanx 5-2 on the Wedge and X-ray Film.

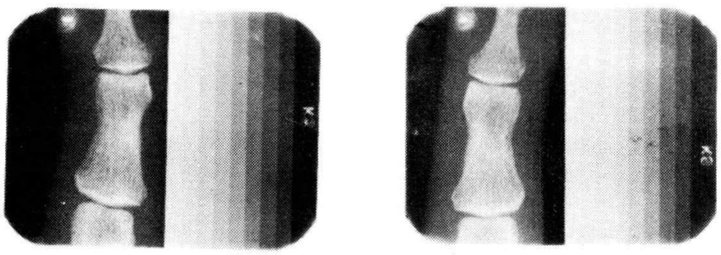

Figure 4. Typical X-ray of Adult Phalanx 5-2, Right and Left Hands.

metric analysis. (Figure 5, pg. 57). Density of phalanx 5-2 was measured against the known density of the aluminum wedge. Densitometric measurements were recorded in thousandths of an inch.

Exercise Program (Treatment)

All subjects participated in a regularly scheduled physical activity (jogging) program for one hour a day, three days a week (Monday, Wednesday, Friday), for a 12-month period. Exercise sessions were under the direction of a certified exercise leader of the LaCrosse Adult Fitness Program. Each exercise session consisted of a 10-minute warm-up period (stretching and flexibility), 30-40 minutes of walking/jogging, and a 5-10 minute cool-down period (walking until exercise heart rate had returned to within five beats of pre-exercise heart rate). The exercise prescription for each subject was based on a percentage of the age-adjusted maximum heart rate dependent on results of the laboratory evaluation. The prescribed target heart rate (THR) was used to monitor intensity of exercise. Participants took their heart rate in a standing position using either the corotid or radial pulse.

Detailed records were kept each exercise session including such items as pre- and post-exercise heart rate, body weight, duration and intensity of exercise.

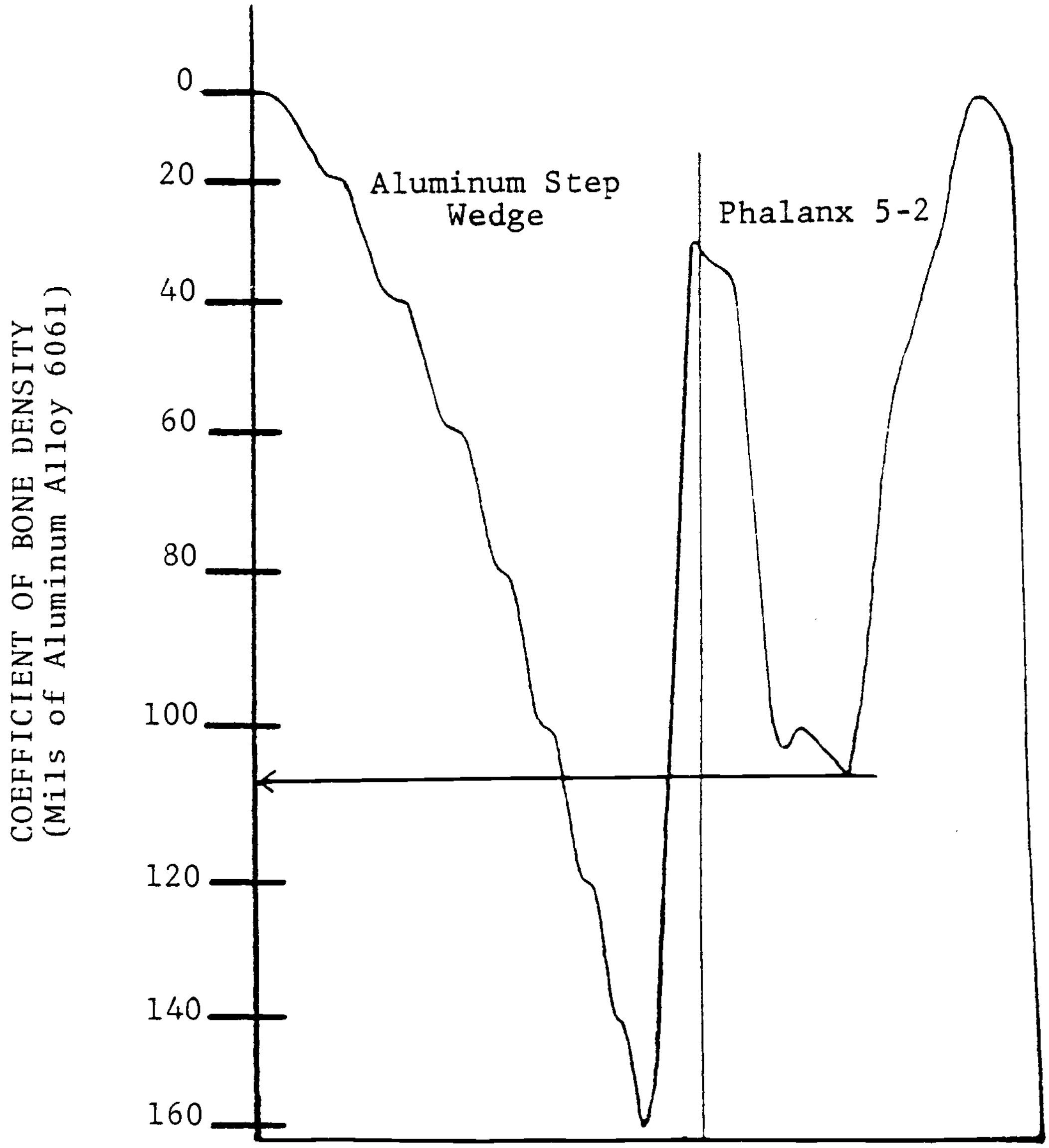

Figure 5. Typical Densitometric Tracing of Adult Phalanx 5-2.

Statistical Analysis

The paired t-test was used for the first null hypothesis to determine if a significant difference existed between the pre-test measures and the nine-month measures and between the pre-test measures and the 12-month measures (22, 69, 86).

The statistical tool utilized for the second null hypothesis was the one-way analysis of covariance (fixed design) using the F statistic to determine if significant differences existed between the measurements of males and females. The pre-test served as the covariant for the study and as the reference for comparison of the nine-month and 12-month tests (22, 86).

TABLE 3. ANOCOVA Table.

Source of Variation	Adjusted			
	df	SS	MS	F
Between Group	1	A	A/1	MS_{Grp}/MS_{error}
Within (error)	9	B	B/9	
Total	10			

Hypotheses

Hypotheses to be tested were:

1. There was no significant difference in bone density measurements of adults due to the 12-month physical activity program.

H_0: $\mu D = 0$

H_1: $\mu D \neq 0$

2. There was no significant difference in bone density measurements of adults due to the 12-month physical activity program when sex was considered.

H_o: $\mu_1 = \mu_2$

H_1: $\mu_1 \neq \mu_2$

The .05 level of confidence was used to test the hypotheses of this study.

Due to the small sample size in this study, the power of the statistical tool was reduced. Power is the probability of rejecting the null hypothesis for a given significant criterion. Assuming an effect size of .80, the power level of the statistical test was .78 (21).

CHAPTER IV

ANALYSIS AND DISCUSSION OF DATA

The primary purpose of this study was to determine the effects of a 12-month physical activity (jogging) program on the bone density of cardiac-prone participants in the Adult Fitness Program at the University of Wisconsin-LaCrosse. A comparison was also made of the bone density of males and females to determine if there was a difference in alterations in bone density due to physical exercise when sex was considered. Seven male and five female volunteer participants served as subjects for this investigation. Table 4 presents the physical characteristics of the subjects.

TABLE 4. Physical Characteristics of Subjects (age, height, body weight).

Sex	Variable	Mean	Standard Deviation	Range
Male	Age (yrs.)	38.00	4.63	31- 45
n = 7	Height (in.)	70.43	3.05	68- 75
	Weight (lbs.)	187.00	26.19	143-232
Female	Age	45.50	10.45	31- 62
n = 5	Height	66.30	2.04	63- 68
	Weight	154.80	24.75	122-187

Physical Activity Inventory

All subjects completed a life-time physical activity inventory to give an overview of their activity profile (Table 5) which might be indicative of their initial bone density measurement.

TABLE 5. Activity Profile and Initial Bone Density of Subjects.

Sex	Age	Participation in Regular Physical Activity (years) High School	College	Post College	Initial Bone Density
Males					
01	39	3	-	-	101
02	33	3	4	Continuous	144
03	43	4	1	-	140
04	38	Heavy farm labor throughout life			138
05	45	4	-	-	135
06	31	3	-	-	119
07	37	3	-	-	130
Females					
08	62	Sedentary life style			94 PM
09	46	4	4	-	103 PM*
10	49	4	4	-	98 PM*
11	40	3	4	-	107
12	31	Sedentary life style			80

PM = postmenopausal
* = hysterectomy middle 30's

Six of the seven male subjects had participated in at least high school athletics, two had been involved in college athletics. One subject had been active in farm work most of his life. Six males indicated no participation in any type of fitness or sport activity since high school or college (15-26 years) and considered themselves sedentary and in average to low physical condition. The highest initial bone density reading was for the male who participates in basketball and tennis three to four times weekly.

Of the five female subjects, three had participated in high school and college athletics; two had been physically inactive their entire life which is possibly why their initial bone density readings were low (80 and 95). The lowest bone density reading was for the youngest female. All five subjects had been relatively sedentary for the past 20-30 years before entering the Adult Fitness Program at the University of Wisconsin-LaCrosse.

Nutritional Analysis

The nutritional survey indicated there had been no change in basic eating habits during the course of the study. The average calcium intake was 770 mg/day for the males and 650 mg/day for the females. These findings agree with nutritional surveys which indicate that on the average, adults in the United States consume less than the recommended daily allowance for calcium (8, 42).

Statistical Treatment

Statistical analysis resulted in rejection of the first null hypothesis:

> There was no significant difference in bone density measurements of adults due to the 12-month physical activity program.

The paired t-test was utilized to test this hypothesis. Data input was comprised of the bone density measurements for the 12 subjects. For the pre- to nine-month measurement the computed t value was 4.23. For the pre- to 12-month measurement the computed t value was 2.49. The value of t should be $\geq$ 2.20 for the .05 level of significance. The computed t values were considered significant and the null hypothesis was rejected. Statistical data for the t-test are found in Tables 6 and 7 on page 64.

Statistical analysis resulted in rejection of the second null hypothesis:

> There was no significant difference in bone density measurements of adults due to the 12-month physical activity program when sex was considered.

TABLE 6. Pre-test to 9-month Test. Paired t-test Results.

Variable	Mean*	Mean*	Difference Standard Deviation*	Standard Error*	t value	Level of Significance
Pre-test	115.58	9.67	7.92	2.29	4.23	.001
9-month test	125.25					

* Measurement in Thousandths of an inch.

TABLE 7. Pre-test to 12-month Test. Paired t-test Results.

Variable	Mean*	Mean*	Difference Standard Deviation*	Standard Error*	t value	Level of Significance
Pre-test	115.58	3.75	5.23	1.51	2.49	.030
12-month test	119.33					

* Measurements in thousandths of an inch.

The one-way analysis of covariance (fixed design) using the F statistic was utilized to test the second null hypothesis. The pre-test served as the covariant and as the reference for comparison.

A comparison of bone density means for the pre- to nine-month measurement is presented in Table 8.

TABLE 8. Pre- and 9-month Test Means and Mean Differences for Bone Density. (Thousandths of an inch.)

Group	Pre-test	9-month Test	Difference
Males	129.571	137.000	7.429
Females	96.000	108.800	12.800

Both males and females appear to have experienced considerable increases in bone density from the pre- to nine-month measurements. Table 9 presents the results of an analysis of covariance which tested the difference for significance between these two groups.

TABLE 9. Analysis of Covariance of the Difference Between Pre- and 9-month Bone Density Measurements.

Source of Variation	df	Adjusted Sum of Squares	Adjusted Mean Squares	F
Between Group	1	39.524	39.524	6.089
Within (error)	9	57.636	6.404	

F must be $\geq$ 5.12 for .05 level of significance.

The observed F indicated a significant difference between the increases in bone density of males and females. Comparison of the mean differences for these two groups indicates that the females experienced significantly greater increases in bone density than the males for this measurement period.

A comparison of bone density means for the pre- to 12-month measurement is presented in Table 10.

TABLE 10. Pre- and 12-month Test Means and Mean Differences for Bone Density (Thousandths of an inch).

Group	Pre-test	12-month Test	Difference
Males	129.571	131.286	1.715
Females	96.000	102.600	6.600

Both males and females realized increased bone density from the pre- to the 12-month measurement. Table 11 presents the results of an analysis of covariance which tested the difference for significance between these two groups.

TABLE 11. Analysis of Covariance of the Difference Between Pre- and 12-month Bone Density Measurements.

Source of Variation	df	Adjusted Sum of Squares	Mean Squares	F
Between Group	1	35.382	35.382	6.546
Within (error)	9	48.647	5.406	

F must be ≥ 5.12 for .05 level of significance.

The observed F indicated a significant difference between the increases in bone density of males and females. Comparison of the mean differences for these two groups again indicates that the females experienced significantly greater increases in bone density than the males for this measurement period.

Discussion

The null hypotheses of this study stated that a 12-month physical activity program would not affect bone density in adults, and also, that there would be no difference in the changes experienced by males and females. Both null hypotheses were rejected.

This study demonstrated that physical activity plays an important role in maintaining and increasing bone mineral content in cardiac-prone adults. These findings concur with results presented by Smith (72) who stated that "the increase in bone mineral is consistent with the concept that appositional bone growth is a function of adaptation to stress." The exact mechanisms of increase in bone mineral cannot be ascertained from this study. Possible mechanisms involve increased calcium absorption, increased circulation in the bone and/or the gravitational and muscular stress affecting bone cellular activity.

The average bone density increase from the pre-test to the nine-month measurement was greater than the percentage increase for the 12-month period (7.7 and 3.1 percent respectively). Accounting for this decrease in bone density from nine to 12 months is open to question. Some possible contributing factors, however, are:

1. Attendance: A decreased percentage of attendance at exercise sessions (average attendance decreased from

80 to 71 percent).

2. Sample size: Due to the small number of subjects, extreme scores would have a more profound effect on the results.

3. Dietary: A low calcium intake would possibly allow for a more rapid decline in bone density when exercise which stimulates calcium absorption is greatly diminished.

One subject varied in bone density measurements from an initial value of 80, increasing to 105 at nine months and then declining to 88 at the 12-month assessment. This same subject's attendance at exercise sessions decreased from 86 percent to 23 percent from nine months to 12 months respectively. Dietary calcium intake was also low for this subject (631.7 mg/day).

Further analysis of the data indicated that the males in this study had denser bones than the females which agrees with the findings of Albanese (18) and Emiola and O'Shea (27). Bone density for males was 24 percent greater than the females at the beginning of the investigation. For the nine-month measurement, the average bone density of the males was 137.0 with a standard deviation of 13.24 which represented a 5.42 percent increase from the initial assessment. The females' average bone density for this same measurement period was 108.8 with a standard deviation of 4.87 which represented a 11.76 percent increase The values for the males at the 12-month assessment were: mean, 131.29; standard deviation, 9.16; percent increase 1.3. For the same measurement period, the values were as follows for the females: mean, 102.0; standard deviation, 7.42; percent increase, 6.43. (Table 12, pg. 72; Figure 6 pg. 71). The findings of this study indicate that a physical activity (jogging) program resulted in greater bone density increases for females than for males. A possible explanation for this result could be the low initial bone density measurement for the females. The initial bone density coefficient for females was 96 which is slightly lower than the normal levels (coefficient of 100) for subjects of their age while that of the males was slightly higher (129.57 as compared to 125) (7). Possibly the "law of diminishing returns" which applies to other physiological parameters also applies to bone density. This law states that the amount of stress necessary to elicit a continual improvement rises as an individual nears their maximum potential (56). Therefore, the males being above average in bone density initially would experience less increase.

The information generated by this study has broad clinical implications. The results lend support to the already accumulated evidence which establishes the importance of endurance-type fitness activities in improving and

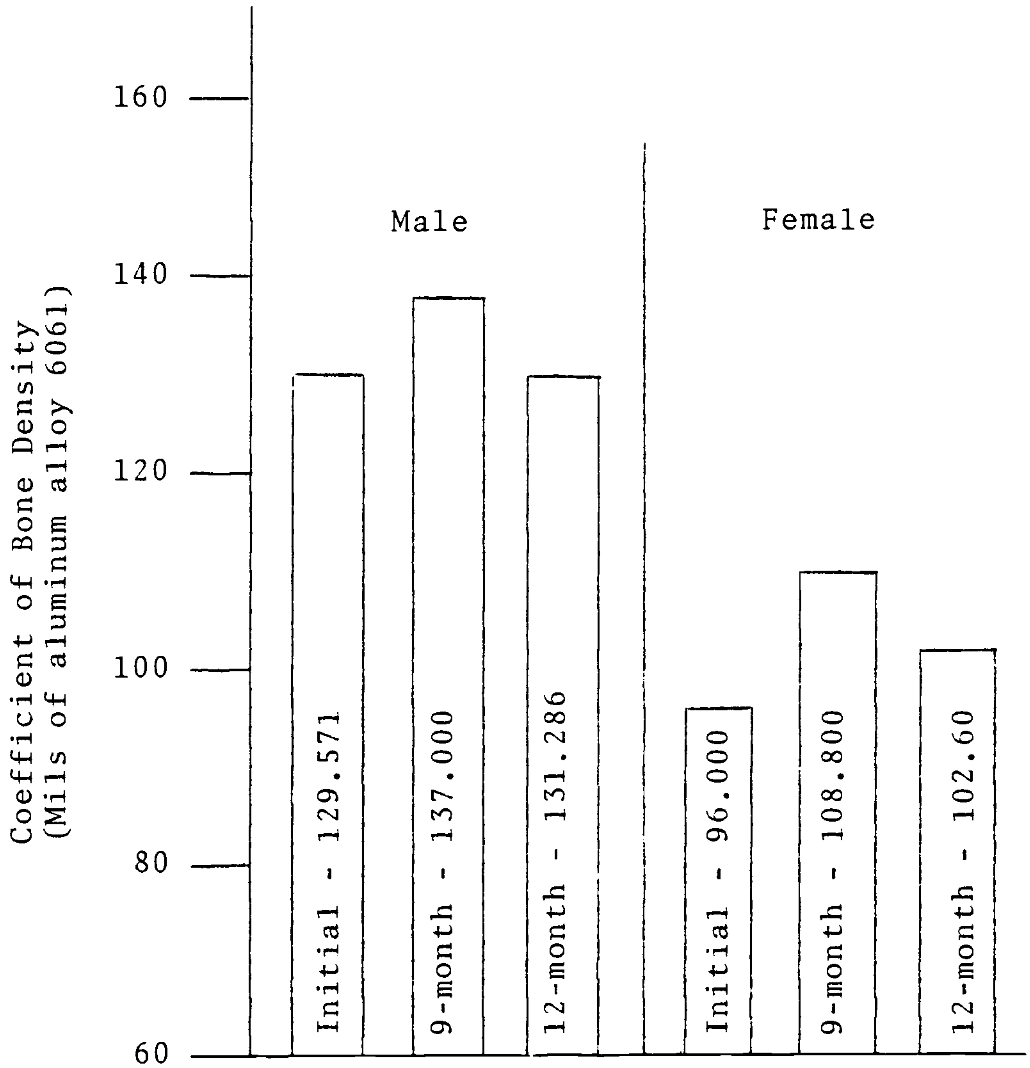

Figure 6. Mean bone density of males and females by measurement period.

(Note: See page 69 for explanation of decrease in bone density from the 9-month to the 12-month measurement.)

TABLE 12. Mean, Standard Deviation, and Percent Increase for the Initial, 9-month, and 12-month Measurements. (Thousandths of an inch).

	Mean	Standard Deviation	Percent Increase
Males:			
Initial	129.57	13.87	
9-month	137.00	13.24	5.42
12-month	131.29	9.16	1.33
Females:			
Initial	96.00	9.17	
9-month	108.80	4.87	11.76
12-month	102.60	7.42	6.43

maintaining not only healthy bones but also the cardiovascular system and many other aspects of health and physical well-being. The results are thus important to cardiac rehabilitation and adult fitness programs. For example, medications taken by cardiac patients, and adults in general, have varying effects on individuals. Certain medications have been demonstrated to impede calcium absorption (antacids, tetracyclines, laxatives, diuretics and heparin) (7). This decrease in calcium absorption can be a contributing factor in the development of osteoporosis in adults and especially the elderly. Increased absorption of calcium is stimulated by physical exercise. In this investigation, a regular jogging program positively affected bone density in cardiac-prone adults. It is possible, therefore, that this mode of therapy could reverse or at least decrease the bone loss influenced by various medications.

Epidemiological surveys have reported that a very high percentage of the osteoporotics in this country are postmenopausal women. The significant increase in bone density experienced by the females in this study indicates that physical activity can reverse the loses in bone density normally experienced by postmenopausal women. Therefore, the inclusion of endurance-type activities in adult fitness programs could conceivably decrease the incidence of osteoporosis in the female population.

This research established the clinical importance of regular physical activity (jogging) in maintaining bone density in cardiac-prone individuals. Physical exercise may be at least part of the answer of the social, medical, and economic problem of an ever increasing incidence of osteoporosis. Also, exercise does not have the detrimental side effects, such as endometrial carcinoma and renal stones, indicated by some researchers to be inherent in the present treatments (11, 77). Therefore, exercise should be considered as an essential part of the prescription in the prevention and treatment of osteoporosis.

The quantitative radiographic technique utilized in this investigation was found to be a reliable technique for assessing bone density in free-living adults. The use of a dental x-ray machine makes it possible to take radiographic measurements with minimal exposure to x-ray. Phalanx 5-2 indicated increased bone density during the course of this study which supported other research (47, 65, 80). Shephard (70) feels that measuring the little finger may not be completely representative of what is happening in leg bones where the major stress occurs. However, in Dalen's (23) research with cross country runners, comparable density increases were experienced in the humerus (non-weight bearing) as well as the femur (weight bearing).

The technique for bone density measurement applied in this study has several possibilities for use in detecting problems in bone health related to bone density. Physicians could employ this technique as a regular part of physical examinations to assess the bone health of individuals in much the same way as stress tests are used to determine aerobic fitness. Also, possibly skeletal stress injuries in athletes are a manifestation of weak bones. This technique could, therefore, be employed in athletic training and sports medicine to assess the bone health of athletes who experience this type of injury.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

Purpose

The primary purpose of this study was to determine the effects of a 12-month physical activity (jogging) program on bone density of cardiac-prone participants in the Adult Fitness Program at the University of Wisconsin-LaCrosse. The secondary purpose determined if there was a difference in bone density alterations due to physical activity when sex was considered.

A review of the literature revealed a lack of longitudinal scientific investigation regarding the effects of exercise on bone density in adults.

Method

Seven male and five female cardiac-prone participants in the Adult Fitness Program volunteered to be subjects for this research. A pre-, nine-month and 12-month assessment using the quantitative radiographic technique measured the bone density. The site of measurement was the second phalanx of the fifth digit of each hand.

The paired t-test was selected as the appropriate statistic for the null hypothesis regarding effects of physical activity on bone density. One-way analysis of covariance was selected as the appropriate statistic for the null hypothesis regarding effects of physical activity on bone density when sex was a consideration.

Results

The results of this study indicated that a regular prescribed physical activity (jogging) program stimulated increases in bone density of cardiac-prone individuals in the Adult Fitness Program at the University of Wisconsin-LaCrosse.

This research also established that females in this study experienced bone density increases which were statistically greater than those of the males in response to the prescribed physical exercise.

A decrease was noted in average bone density from the nine-month to the 12-month measurement, however, both assessments were significantly greater than the initial value. This apparent decrease may be due in part to some rather substantial decreases in bone density experienced by one or two of the subjects.

Conclusions

The following conclusions have been drawn from the results of this investigation:

1. The physical activity program as outlined in this study increased bone density of cardiac-prone adults in the Adult Fitness Program at the University of Wisconsin-LaCrosse.

2. Cardiac-prone females (age 31-62) realized a greater increase in bone density as a result of the physical activity program as outlined in this study than cardiac-prone males (age 31-45).

Recommendations

Present technology permits an accurate assessment of bone density in studies involving a wide range of problems associated with building and maintaining strong bones. To further expand our knowledge as to the effects of exercise on bone density, research in the following areas is recommended:

1. Replicate this investigation with a larger sample and less age variance.

2. As a preventive medicine concept, determine the level of exercise necessary to build and maintain healthy strong bones in a stratified population (i.e., sex, age groups).

3. Establish the effects of various modes, intensities and durations of exercise on building and maintaining strong bones.

4. Develop tables indicating how much exercise is necessary to develop and maintain healthy bones based on age, sex, and occupation.

5. Determine the effects of changes in body weight on bone density, considering both gains and losses in weight, especially those associated with the aging process.

6. Investigate the effects of various weight loss diets on bone density and as predisposing factors to the development of osteoporosis.

7. Study the long term effects of some common prescription drugs on bone health especially in the elderly (i.e., antacids, diuretics).

8. Determine if some of the more common stress injuries to the skeletal system associated with athletics, such as stress fractures and shin splints, are a manifestation of weak bones.

9. Analyze the bone density of athletes in various sports comparing those who have never had skeletal stress injuries with those who have.

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APPENDICES

APPENDIX A

Progress Report

LA CROSSE EXERCISE PROGRAM
ADULT FITNESS
DIRECTOR, CLIFTON H. DE VOLL P.ED.D.

MAR 1980 PROGRESS REPORT FOR 5294

REFERING PHYSICIAN

*EXERCISE
MONTHLY TOTAL TRACK DISTANCE IS 58.0 MILES, DAILY AVERAGE OF 5.3 MILES
PREVIOUS MONTH TRACK DISTANCE IS 68.0 MILES, DAILY AVERAGE OF 5.2 MILES
MONTHLY SUPPLEMENTAL DISTANCE IS 83 MILES.
GRAND TOTAL TRACK DISTANCE IS 1289 MILES SINCE FEB 1979.

FOR THE PAST MONTH YOU EXERCISED AT AN AVERAGE HEART RATE OF 25 (150 BEATS PER MINUTE), WITH A HEART RATE PRESCRIPTION OF 27 (162 BEATS PER MINUTE). THE DIFFERENCE BETWEEN YOUR ACTUAL EXERCISE HEART RATE AND YOUR PRESCRIBED HEART RATE IS 2 (12 BEATS PER MINUTE).
GOOD JOB. STICK WITH IT.

* WEIGHT CONTROL
YOUR AVERAGE WEIGHT FOR THE MONTH WAS 138 LB. (63 KG). UPON ENTERING THE PROGRAM IN FEB 1979 YOUR WEIGHT WAS 143 LB. (65 KG). SINCE THEN YOU HAVE LOST 5 LB. (2 KG) AND ARE 2 LB. (1 KG) UNDER YOUR WEIGHT GOAL OF 140 LB. (64 KG).

* CALORIC EXPENDITURE (1 LB = 3500 CALORIES)
YOU EXPENDED 6,395 CALORIES (1.8 LB., 0.8 KG) EXERCISING DURING THE PAST MONTH, A DAILY AVERAGE OF 581 CALORIES (.17 LB., .08 KG). THE PREVIOUS MONTH, YOUR EXERCISE USED 7,350 CALORIES (2.1 LB., 1.0 KG), AN AVERAGE OF 565 CALORIES (.16 LB., .07 KG) PER EXERCISE SESSION. THE TOTAL NUMBER OF CALORIES YOU HAVE UTILIZED EXERCISING SINCE APR 1979 HAS BEEN 137,668 (39.3 LB., 17.9 KG). IT IS IMPORTANT TO REALIZE THAT THESE POTENTIAL WEIGHT LOSS VALUES ARE BASED ONLY ON THE NUMBER OF CALORIES YOU UTILIZED EXERCISING AND THEREFORE DO NOT REFLECT CALORIC INTAKE.

* ATTENDANCE
SINCE ENTERING THE PROGRAM, YOU HAVE ATTENDED 93% OF THE EXERCISE SESSIONS AND OVER THE PAST 3 MONTH PERIOD YOUR ATTENDANCE PERCENTAGE HAS BEEN 89%. OUT OF 13 POSSIBLE EXERCISE SESSIONS LAST MONTH YOU WERE PRESENT FOR 11 FOR A MONTHLY PERCENTAGE OF 85%.
THE MORE OFTEN YOU ATTEND, THE GREATER THE BENEFITS WILL BE AND THE BETTER YOU'LL FEEL.

THE INFORMATION CONTAINED IN THIS REPORT IS FOR YOUR BENEFIT. ANY QUESTIONS REGARDING IT SHOULD BE REFERRED TO YOUR EXERCISE LEADER.

APPENDIX B

Physical Activity Inventory

PHYSICAL ACTIVITY INVENTORY

NAME ______________________________ DATE ____________

Reference Number ____________________

A. FORMER ATHLETES

1. Did you participate in any competitive athletics (above intramural level)? _____yes _____no
2. If yes, in what sport(s)? ______________________
3. How long did you compete and at what level?

   High School __________ yrs.

   College ____________ yrs

   Private Club, AAU, etc. __________ yrs.

   Beyond College __________ yrs.
4. When did you stop competing? ______________

B. FORMER INTRAMURAL & RECREATIONAL ATHLETES

5. Did you participate regularly (minimum twice/week) in any intramural competition or any vigorous individual physical activity when you were in high school or college?

   _____yes _____no
6. If yes, what activities? ______________________

   ____

C. NON-ATHLETES

7. Did you participate in any regular (minimum twice/week) physical activity or heavy manual labor during your school years?

   _____yes _____no
8. If yes to Question 7:

Name of Activity	Frequency (hrs/week)	No. of Years

D. ALL SUBJECTS

9. Have you ever engaged in any heavy physical manual labor on a regular basis? Example: work on a farm or ranch

Kind of work	Frequency (hrs/week)	No. of Years

10. Do you currently participate in any regular (minimum twice/week) strenuous physical activity (job related or recreational)?

Name of Activity	Frequency (hrs/week)	No. of Years
Job Related		
Recreational		

11. How far do you think you walk each day? ______________

12. What is your occupation? ______________________

13. Do you consider your occupation to be:

_____ Inactive _____Active _____ Heavy Work

15. How will you rate your PRESENT overall intensity of physical activity?

_____Very high _____ high _____ Average _____ Low

_____ Very Low

16. Have you ever had a broken bone? _____ yes _____ no

17. If yes to question 16:

    Location of break ______________________________

    Cause ______________________________

    Age when break occurred ______________________________

E. WOMEN ONLY

18. Check one of the following:

    _____ Pre-menopause

    _____ Post-menopause

    _____ Hysterectomy

APPENDIX C

Dietary Information

Name ____________________

I.D. NO. ____________________

DATE ____________________

LA CROSSE EXERCISE PROGRAM

Dietary Information

In conjunction with the dietitian, please complete the following dietary information questionnaire.

1. How much exercise do you receive in a normal day, other than through the Adult Fitness Program?____________________
____

2. What is your occupation? ____________________

3. What medication are you presently taking? ____________________
____

4. Are you presently on a diet? ______ If so, has the diet been suggested by your physician? ______ Describe the diet: ____
____
____

5. Where are your meals eaten? ____________________

6. Who prepares your meals? ____________________

7. How often do you eat in restaurants? ____________________
____

8. Does your eating pattern vary on weekends? ____________________
____
____

"NORMAL" TWENTY-FOUR HOUR EAT AND DRINK HABITS

Indicate below the food and drink you normally consume daily. It is extremely important that you be honest as to the 24-hour period regarding what you eat, drink, etc.

Dietary Information
Page 2

BREAKFAST | NOON MEAL | EVENING MEAL

Snack | Snack | Snack

9. Do you consume alcohol on a regular basis? ________ If so, in what form is the drink? ______________________.
How much would you consume in an average day? ____________
In the above 24-hour period, was anything omitted which normally would not have been? __________. Explain: ______________

____

____

10. Do you take any protein, vitamin or mineral supplements? ______
Amount ____________ Kind ______________________

____

G E N E R A L   S U M M A R Y

*** 7:12 A.M. MONDAY 13 MARCH 1978 ***

NUTRIENT		MEAN OF 1 DAY(S)	RDA	% RDA OF FOOD	% OF TOTAL CALORIES
CALORIES	KC	2756.7	2400.0	114.9 +	
PROTEIN	GM	95.3	56.0	170.2 +	13.8
FAT	GM	142.4			46.5
CARBO	GM	286.1			39.7
ALCOHOL	?GM	0.0*			0.0
VIT A	IU	10645.5	5000.0	212.9 +	
VIT D	?IU	0.0*			
VIT E	?IU	0.0*	15.0	0.0*-	
VIT K	?MC	0.0*			
FOLIC ACID	?MC	0.0*			
PANETHENIC	?MG	0.0*			
THIAMIN	MG	1.9	1.2	155.2 +	
RIBOFLAVIN	MG	2.2	1.5	146.0 +	
NIACIN	MG	27.5	16.0	172.1 +	
B 6	?MG	0.0*	2.0	0.0*-	
B 12	?MG	0.0*	3.0	0.0*-	
ASCORBIC	MG	101.0	45.0	224.5 +	
CALCIUM	MG	747.6	800.0	93.5 -	
PHOSPHORUS	MG	1428.2	800.0	178.5 +	
POTASSIUM	MG	2229.4			
MAGNESIUM	?MG	0.0*	350.0	0.0*-	
SODIUM	MG	2753.3			
IRON	MG	14.3	10.0	142.7 +	
ZINC	MG	0.1*	15.0	0.5*-	
IODINE	MG	0.0*	110.0	0.0*-	
COPPER	MC	0.0*			
MAGENESE	?MG	0.0*			
CHROMIUM	?MC	0.0*			
LEAD	?MC	0.0*			
FAT	GM	142.4			
SAT FAT	MG	42.3			
OLEIC ACID	IU	68.3*			
LINOLEIC	MG	21.3*			
CHOLESTER	MG	229.1			
FIBER	?MC	0.0*			

NAME ______________________________

ONE DAY DIET

I.D. NO. ________________________

Week ____________________

Please record all items consumed (foods, beverages) for ________________ this week. It is important to include everything and to be as accurate as possible on the amount eaten. Please bring this form, completed, to your next exercise session and give it to your student exercise leader. Thank you.

NAME OF FOOD/BEVERAGE	AMOUNT CONSUMED	

APPENDIX D

Informed Consent and Information Letter

INFORMED CONSENT FORM

University of Wisconsin - LaCrosse
LaCrosse, Wisconsin 54601

Project Title: The Effects of a 12-Month Physical Activity Program on Bone Density of Adults as Assessed by Radiographic Technique

Principal Investigator: Sandy Price

I, ______________________________, being of sound mind
(Name of Subject)
and __________ years of age, do hereby consent to, authorize and request the person named above (and her co-workers, agents, and employees) to undertake and perform on me the proposed procedure, treatment, research or investigation (Herein called "Procedure").

I have read the informational letter, and I have been fully advised of the nature of the Procedure and the possible risks and complications involved in it, all of which risks and complications I hereby assume voluntarily.

I hereby acknowledge that no representations, warranties, guarantees or assurances of any kind pertaining to the Procedure have been made to me by University of Wisconsin-LaCrosse, the officers, administration, employees or by anyone acting on behalf of any of them.

I understand that I may withdraw from the program at any time.

Signed at __________________________ this __________

day of ____________________, 1979, in the presence of the witnesses whose signatures appear below opposite my signature.

WITNESSED BY:

__________________________ __________________________
(Subject)

____

27 January 1979

Dear ______________________:

As part of my graduate program at Oregon State University, I am conducting a research study to determine the effects regular physical activity may play in the bone density of adults.

Decreases in bone density result in a condition called osteoporosis which literally means porous bones. An osteoporotic bone is not as strong as normal bone. Osteoporosis is one of the most common and yet poorly understood dibilitating disorders of middle age. It has been estimated that at least 4 million persons in the United States have a significant degree of osteoporosis. Fractures of osteoporotic origin constitute one of the major disabling afflications of the elderly. However, osteoporosis is not limited to the aged. Research reveals that subnormal bone density exists in 25% of all "healthy normal" persons of both sexes as early as age 25.

It is a known fact that physical activity can increase bone density in pre-adult years (i.e., athletes have denser bones than non-athletes, etc.). However, the effects of physical activity on the bone density of adults is not yet clearly understood. It is hoped that this research may shed some light on this important subject.

In as much as the participants in the Adult Fitness Program are involved in controlled exercise on a regular basis, this program is ideal to determine if, indeed, physical activity can positively affect the bone density of adults.

By volunteering as a subject for this study, you will be required to do three things (at no cost to you) in addition to the regular laboratory evaluations of the Adult Fitness Unit. These three items are:

1. Physical Activity Inventory. Fill out a physical activity inventory detailing the past and present physical activities in which you are or have been engaged on a regular basis.

2. Bone Density Measurement. Submit to a bone density measurement at the beginning of the study and again 9 and 12 months thereafter. The bone density measurement involves taking an x-ray of the second phalangeal segment of the small finger (referred to

as phalanx 5-2) of your right and left hands. These x-rays will be taken with a dental x-ray machine in the Human Performance Laboratory at the University of Wisconsin-LaCrosse. The initial x-rays will be taken at the same time the initial laboratory procedures are conducted. The other two measurements (9 and 12 months), will be arranged at your convenience.

There is no known adverse effect of the exposure of this small part of a finger to a dental x-ray machine. According to the Division of Radiological Health, U.S. Public Health Service, the American Dental Association, and the American Academy of Oral Roentgenology, the amount of radiation from dental x-rays is less than that received from natural sources, such as cosmic rays from outer space (sun). The actual exposure time for each x-ray will be 0.4 seconds.

This study and the procedures to be used have been approved by the LaCrosse Exercise Program Executive Board consisting of physicians in the LaCrosse area.

3. <u>Nutritional Analysis</u>. In addition to the regular preliminary nutritional analysis and dietary conference with a nutritionist, you will be asked to keep track of your food and drink intake for three 24-hour periods again during the study.

All information gathered shall remain anonymous and participants shall be referred to by their identification number only.

I am grateful for your willingness to participate in this study. Thank you.

Sincerely,

Sandy Price
Assistant Professor
Department of Physical Ed
136 Mitchell Hall
UW-LaCrosse
LaCrosse, Wisconsin 54601
785-8179