PATTERNS OF HISTORICAL PHYSICAL ACTIVITY AND THE IMPACT ON CURRENT STATUS OF OSTEOPOROSIS IN THE OLDER POPULATION

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Patterns of Historical Physical Activity and the Impact on Current Status of

Osteoporosis in the Older Population

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The problem is not always the problem…………………………………………
the problem may be the way in which we choose
  to deal with the problem.

—Peggy Lee Ranke
ABSTRACT OF THE THESIS

Patterns of Historical Physical Activity and the Impact on Current Status of Osteoporosis in the Older Population
by
Peggy Lee Ranke
Master of Public Health
San Diego State University, 2011

INTRODUCTION: Chronic diseases are of major concern in public health and are huge contributing factors for high healthcare expenditures; however, this study focuses on osteoporosis. Osteoporotic fractures are associated with pain, disability, and societal dependency with estimated annual costs in the United States of $7 to $20 billion. Therefore, it is highly significant to study preventive measures in young and early adulthood to decrease the likelihood of osteoporosis at an older age. This study’s intention is to recognize if osteoporosis risks are preventable or significantly reduced with physical activity and its potential impact of future osteoporosis.

METHODS: Participants: 1682 Rancho Bernardo, California residents participated in a longevity study between years 1972 and 2011 with ongoing study. Exactly 688 participants were male (40.9%) and 994 (59.1%) were female. All participants were between 55 - 90 years old. Measurement: A Paffenbarger (modified) questionnaire was used to obtain former and current exercise information, including frequency and level of physical activity. Physical activity level is categorized as mild, moderate, or vigorous. Osteoporosis status was defined as normal, osteopenia, or osteoporosis dependent upon bone mineral density (BMD) measurement using dual energy X-ray absorptiometry (DXA). After controlling for risk factors, multiple logistical regression was used to determine the association between past physical activity and occurrence of osteoporosis.

RESULTS: People who had past moderate or vigorous physical activity at least 5 times a week are 0.627 times as likely to develop osteoporosis than people who do not engage in moderate or vigorous physical activity at least 5 times a week. People 71-80 years of age were 0.200 times as likely to develop osteoporosis than people age 55-70 (OR=0.200; 95% CI: 0.124-0.321) and people 81-90 years of age were 0.481 times as likely to develop osteoporosis than those who were 55-70 (OR= 0.481; 95% CI: 0.291-0.794). Men are 0.529 times as likely to develop osteoporosis as females or older old people who engaged in moderate or vigorous physical activity at least 5 times a week (OR= 0.529; 95% CI: 0.392-0.713).

CONCLUSION: Past moderate to vigorous physical activity at least 5 times a week during age 30s – 50s is associated with increased bone mineral density (BMD) at older years. These data suggest a protective effect of current and lifelong physical activity on hip BMD in older men and women.
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<td>BMD</td>
<td>Bone Mineral Density</td>
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<td>WHO</td>
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<td>Center for Disease Control</td>
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<td>National Osteoporosis Foundation</td>
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<td>Gross Domestic Product</td>
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<td>Rancho Bernardo</td>
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CHAPTER 1
INTRODUCTION

1.1 THE AGING POPULATION AND CHRONIC ILLNESS

The title "Year of the Older Person" was designated for 1999 from United Nations demographers in recognition of the global population aging at an unparalleled rate. The confluence of improved health outcomes, medical technology, preventive medicine, decreased death rates, and lower fertility are leading factors as to why the oldest old are the fastest rising sector of the United States population (Kinsella & Velkoff, 2001). While lifetime longevity is a human success story, it poses challenges for policy makers as healthcare cost at all levels and care-giving expenses for the elderly continually rise. In the United States, the number of older people is projected to more than double between 2000 and 2050. In addition, the population aged 85 years and over is projected to increase by 350%, increasing from 12.7% of those 65 and older in 2000 to 20.3% in 2050 (Wiener & Tilly, 2002), suggesting the importance of the healthcare and increasing health expenditure for the aging population.

As Americans are living longer, the prevalence of chronic disorders has emerged (Winters, Wallace, & Sjoquist, 2007). Health expenditures for chronic illnesses cost the United States economy more than $1 trillion per year, an amount that could increase to nearly $6 trillion by 2050 as reported by the Milken Institute (Monford, 2007). The monetary impact of chronic illness is not limited to treating diseases and medical care, but it also puts a huge burden on economic productivity including decreased performance by ailing workers and an increase number of sick days. Many chronic illnesses require long-term healthcare services in the vein of extended hospital stays and nursing home care. Almost half of the United States population has some form of chronic illness or disease which contributes to costly treatments and consumes 75% of the US’s healthcare expenditure (Hoffman, Rice, & Sung, 1996).

Osteoporosis is a chronic illness that poses a major concern in public health and is a contributing factor for high healthcare expenditures. As the population ages globally, the
incidence of osteoporosis-related fractures are expected to rise substantially over the coming decades (Brewer, Williams, & Moore, 2011). Specifically, fractures in the elderly presumably require long-term care that is more likely to cause the greatest strain on resources for personal and family finances, on public resources, and on health expenditure (Brewer et al., 2011). Osteoporotic fractures are associated with pain, disability, and societal dependency, with estimated annual costs of $7 to $20 billion in the United States (Monson, 2008). Of all hospital beds in Europe, 1.0 to 1.5% are occupied by osteoporotic patients, a figure expected to more than double during the next fifty years (Elffors, 1998).

1.2 OSTEOPOROSIS

Osteoporosis is a metabolic skeletal disease described by low bone mass and deterioration of bone tissue, thus increasing bone vulnerability. Bone vulnerability causes the risk of fractures which are associated with chronic illness, chronic pain, disability, and premature death. The aging process increases bone mass loss, which leads to chronic illnesses such as osteopenia and osteoporosis. According to the World Health Organization (WHO) criteria, 30% of Caucasian postmenopausal women in the U.S. have osteoporosis, and 54% have osteopenia. The prevalence of osteoporosis in Caucasian postmenopausal women in the U.S., based on the lowest bone mass at any site, is estimated to be: 14% aged 50-59 years; 22% aged 60-69 years; 39% aged 70-79 years; and 70% aged 80 years or greater (WHO, 2003). Furthermore, approximately 1 in 4 men 50 years and older are anticipated to have a fragility with root cause of osteoporosis fracture in their lifetime (Kanis & Kanis, 1994).

Demographic change (the aging population) is expected to transform the structure, quantity, and quality of healthcare services demanded by older population (Bustacchini et al., 2009). The increase in medical visits, hospitalizations, need for community support, and nursing home admissions will pose a major economic burden on healthcare systems (Brewer et al., 2011). Osteoporosis and related fractures place a substantial financial burden on individuals and society. Considerable financial costs are associated with hospitalization, outpatient care, and long-term care among patients with osteoporosis (Becker, Kilgore, & Morrisey, 2010). Currently, the existing disability and economic burden of osteoporosis is
extensive, and the prevalence of osteoporosis and the future burden will increase significantly with the increase of the aging population (Winters et al., 2007).

It is progressively more vital to quantify the burden of chronic illness in the aging population for planning the necessary health services that will be required in the future years and to measure the anticipated benefits from prevention interventions to potentially decreased disability in older people (Bustacchini et al., 2009). Therefore, it is highly significant to study preventive measures, such as physical activity, in young and early adulthood in order to decrease the likelihood of osteoporosis at an older age. Major benefits of physical activity are to prevent osteoporosis by preserving diminishing bone loss, by decreasing the rate of bone loss, and by maintaining bone density (Drinkwater, 1994).

According to the US Centers for Disease Control and Prevention (CDC), adults should accrue 30 minutes or more of moderate intensity physical activity each day to accumulate a minimum of 150 minutes each week (CDC, 2010). The CDC suggests physical activity provides protective effects against risk for several chronic diseases including osteoporosis (Helmrich, Ragland, Leung, & Paffenbarger, 1991).

1.3 Research Question and Hypothesis

The research question is: how is past physical activity is associated with future osteoporosis? The current study investigates the pattern of past physical activity in 3 levels (mild, moderate, and vigorous) at various ages throughout life, and evaluates the impact of physical activity on future osteoporosis. The results of the present study are expected to imply possible preventive actions that can be taken in adulthood to decrease the likelihood of developing osteoporosis throughout the normal lifetime aging process. The hypothesis for this study is: moderate or vigorous physical activity at ages 30s or 50s increases later life bone mineral density (BMD).
CHAPTER 2

LITERATURE REVIEW

2.1 THE AGING POPULATION AND PREVALENCE OF OSTEOPOOROSIS

The aging populations in developed countries have brought collective attention to the escalating incidence of age-related chronic conditions. Globally, the mean life span is anticipated to lengthen another 10 years by 2050 (CDC, 2003). Older adults are disproportionately affected by chronic illness which contributes to ever increasing health and long-term care costs, disability, and decreasing quality of life. The older adults, who are the fastest growing segment of the U.S. population, increase demands on social services, medical services, and the public health system. According to Public Health and Aging (CDC, 2003), the anticipated increase in the number of older persons will have dramatic consequences for public health, informal care-giving, the healthcare financing and delivery systems, and pension systems. Expenditures for people 65 years and older, per capita, in healthcare is approximated at three to five times more than the expenditure for people 65 years and younger. With continued advances in medical technology and the rapid growth in the number of older persons, increasing strains on long-term care and health spending are anticipated (Jacobzone & Oxley, 2002). As the population ages globally, the incidence of chronic disease osteoporosis-related fractures will rise substantially over the coming decades (Brewer et al., 2011). Chronic illness, specifically fractures in the elderly with a root cause of osteoporosis, presumably will require long-term care that may cause the greater strain on resources (CDC, 2003).

Osteoporosis accounts for approximately 1.5 million new fractures each year, with associated medical charges (including direct, indirect and intangible costs) costing an estimated $60 billion, according to the National Osteoporosis Foundation (Monson, 2008). As the number of individuals over the age of 65 increases and because osteoporosis affects primarily the elderly, the National Osteoporosis Foundation estimates that these costs will increase to $200 billion by the year 2040 (Larsen & Lubkin, 2009). The impact of long term
care and rehabilitation on the economy may be devastating with health expenditures nearing 18.5% of the Gross Domestic Product (GDP) in the United States. Winters et al. (2007) claims that osteoporosis is a concern of worldwide health and economic burden and has also been shown to result in significant costs in other countries. Additionally, in the United States, osteoporotic fractures costs $7 to $20 billion annually, and a significant proportion (over 60%) of the expenditure is from care for hip fractures (Elffors, 1998). Classically, osteoporotic frailty fractures are a result of low bone mass (Elffors, 1998).

### 2.2 OSTEOPOROSIS

Bone is living, growing tissue. Collagen is a protein that provides a soft framework for the bone, and calcium phosphate is a mineral that adds strength to the bone framework that makes up bone (Department of Health and Human Services, National Institute of Health [DHHS], 2011). This combination of collagen and calcium phosphate makes bone flexible and strong, helping it to endure stress. Greater than 99 percent of the body's calcium is found in the bones and teeth. The remaining 1 percent circulates in the bloodstream. Throughout lifetime old bone is removed (a process called resorption) and new bone is added to the framework (formation). New bone is added faster than old bone is removed during childhood and teenage years and bones become bigger, heavier, and denser (Monson, 2011). Bone formation exceeds resorption until peak bone mass (maximum bone density and strength) is reached typically at around age 30. Bone resorption slowly begins to surpass bone formation once peak formation is achieved (Monson, 2011), thus creating an impetus for osteoporosis and osteopenia.

Osteoporosis, meaning porous bones, is derived from the Greek words *osteon* meaning "bone" and *πόρος/poros* meaning "pore" (Alldredge, Koda-Kimble, Young, Kradjan, & Guglielmo, 2009). It is deterioration of bone micro-architecture leading to an increased risk of fracture (Alldredge et al., 2009). In osteoporosis the bones are deteriorating, the bone mineral density is reduced, and the variety and amount of proteins in bone is changed. The term "established osteoporosis" includes the presence of a fragility fracture that is caused by disease leading to weakness of the bone. Osteoporosis may further be classified as primary type 1, primary type 2, or secondary (Alldredge et al., 2009). Primary type 1, or postmenopausal osteoporosis, is most common in women after menopause. Senile
osteoporosis, or primary type 2, occurs after age 75 and is seen in both females and males with a ratio of 2:1. Secondary osteoporosis affects men and women equally and may arise at any age (WHO, 1994).

Osteoporosis is a major public health threat for 44 million Americans of which 68 percent are women (Monson, 2008). Lifetime risk in women is similar to the risk for cardiovascular disease. The risk of dying from hip fracture equals breast cancer mortality (Elffors, 1998). Because the prevalence of osteoporosis and the rate of fractures are much higher in postmenopausal women than in older men, it is typically thought of as a "woman's disease." However, the prevalence of men affected by osteoporosis and fractures is greater than 2.8 million in the United States and many more are diagnosed with osteopenia (Cawthon, 2011). In men 30-70 years of age, osteoporosis is referred to as 'idiopathic osteoporosis' and as 'age-related osteoporosis' in older men (Bleicher et al., 2010).

Osteoporosis can strike at any age (DHHS, 2011). Osteoporotic fractures in men and fracture-related morbidity and mortality in men 50 years of age and older are higher than in women (Bleicher et al., 2010). Osteoporosis is the root cause of 1.5 million fractures annually; 300,000 hip fractures, approximately 700,000 vertebral fractures, 250,000 wrist fractures, and more than 300,000 fractures elsewhere (Monson, 2008). Within the United States 10 million individuals currently have osteoporosis, and 34 million more have low bone mass, placing them at increased risk for developing this disease and frailty fractures (Monson, 2008).

2.3 OSTEOPOROSIS RISK FACTORS AND TREATMENT

Literature shows several associated behaviors attributable to developing osteoporosis and common treatments once osteoporosis is diagnosed.

2.3.1 Risk Factors

Risk factors for developing osteoporosis include: thinness or small frame; family history of osteoporosis; being postmenopausal or having had early menopause; prolonged use of certain drugs such as PREDNISONE; hormone replacement therapy use (HTR); low calcium intake; smoking; functional capacity; alcohol intake; medical factors and physical inactivity. Low body weight is associated with an increased risk for osteoporosis and
fractures (Elffors, 1998). Osteoporosis risks can be reduced with lifestyle changes and sometimes medication. Osteoporosis is a major risk factor for fractures in the elderly (Elffors, 1998).

### 2.3.2 Treatment of Osteoporosis

Treatment may involve both lifestyle changes and medication. Lifestyle change includes diet and exercise, cessation of smoking, and preventing falls. Medication includes vitamin D, calcium, bisphosphonates, and other medications. Exercise to tone muscles may enhance fall-prevention ability.

### 2.4 Physical Activity and Impact on BMD

Research implies that lack of physical activity places an enormous burden both on individual health and on the economy (McKinnon, Bowles, & Trowbridge, 2011), and that larger costs are imposed on society from physically inactive people than from problem drinkers or smokers. Literature suggests that increasing physical activity is a cost-effective means to prevent disease, improve health outcomes, and reduce medical expenses (CDC, 2010). Many studies have evaluated the association between physical activity and bone health. Hip fractures are the most important type of osteoporotic fractures and have been given substantial interest among researchers. Most patients with hip fractures seek clinical services, facilitating use of hip fracture as an end point for BMD (Wolinsky et al., 2009). Most of the prospective studies evaluating the association between physical activity and hip fracture risk have found significant risk reductions among either men or women (Cummings, et al., 1995).

The Rancho Bernardo Study (Greendale, Barrett-Connor, Edelstein, Ingles, & Haile, 1995) evaluated the relationship between leisure time physical activity, BMD, and osteoporotic fractures in a cohort of community-dwelling California adults (1,014 women and 689 men) with a mean age of 73 years between 1988 and 1991. Based on a questionnaire that asked subjects about exercise from the past year and their level of exercise throughout their lifetime and during three periods (teenage years, 30 years old, 50 years old, and a combination to equal lifetime exercise) authors found a positive association between current exercise and BMD at the total hip and at each hip component (i.e. greater trochanter, inter-
trochanter, and femoral neck). Mean hip bone densities of strenuous and moderate current exercisers were higher than those of mild or less than mild exercisers. Lifetime exercise was also positively associated with BMD of the total hip and hip components, and demonstrated a borderline-significant association (p = 0.06) with spine BMD. At the hip, each pairwise comparison between the highest and lowest tertiles of lifetime exercise showed a significant difference. Exercise was unassociated with minimal trauma fracture occurring at any site between 1972 and 1991. Their study concluded that data suggest a protective effect of current and lifelong exercise on hip BMD, but not on osteoporotic fractures in older men and women.

Moayyeri’s (2008) review study with hip fractures claims that moderate-to-vigorous physical activity is associated with a hip fracture risk reduction of 45%. Also, the National Health and Nutrition Examination Survey I follow-up study showed that women who reported moderate-to-vigorous physical activity had a 47% lower risk of hip fracture than those reporting no physical activity (Farmer et al., 1989). A study of osteoporotic fractures found walking to be associated with a significant 30% reduction in hip fracture risk after 4.1 years after they started walking for exercise and 40% reduction in hip fracture risk after 7.6 years of walking in postmenopausal white women (Cummings et al., 1995). Another study found that active women with at least 24 metabolic equivalent hours per week of activity had a 55% lower risk of hip fracture compared with sedentary women with less than 3 metabolic equivalent hours per week (Feskanich, Willett, & Colditz, 2002). Consistently, Moayyeri (2008) concluded that the risk of falling is suggested to be generally reduced among physically active people, although a potential increased risk in the most active and inactive people occur. However, positive effects of physical activity on BMD and bone quality are of a questionable degree for reduction of fracture risk. The Tromso study in Norway found similar protective effects of leisure and work physical activity on weight-bearing fracture sites (hip and ankle) among men but not among women, contradicting other studies results. (Joakimsen et al., 1998). With the exception of Moayyeri (2008), the above studies focus primarily on fractures and falls and contain limited information about the association of physical activity and BMD.

Jaglal, McIsaac, Hawker, and Jaakkimainen (2000) found that the effects of past and recent physical activity (whether moderate or intense) had a significant protective effect on
the risk of hip fractures. The study showed that women were only half as likely to have a hip fracture if they had been active when they were younger versus women who had not been active. They also assessed activity in the past year and in the year prior to the hip fracture in order to estimate recent physical activity levels. They found that women who had been very active in the recent past had no increased protection from hip fractures.

Another study found that minimum to moderate physical activity was associated with beneficial outcomes (Ulrich, Georgiou, Gillis, & Snow, 1999). They concluded that weight-bearing household and occupational activity (minimum to moderate level activity) appeared to be related to BMD and recommended that people increase physical activity throughout life, particularly during early ages, as a means of osteoporosis prevention. On the other hand, there is controversy in the literature concerning the effects of physical activity on BMD. Schöffl et al., (2008) explored the impact of physical activity on BMD strength differences of BMD. Based on a sample of approximately 300 postmenopausal women without diagnosed bone diseases or medication, they claimed that consistent exercise or variations in physical activity had no effect on bone and that the most important variable for explaining BMD was weight and lean body mass. Their study concluded that habitual physical activity probably has no beneficial impact on BMD, but that weight and lean body mass was the leading predictor of BMD in normal elderly women.
CHAPTER 3

METHODS

This research investigates the pattern of past physical activity and the association of future osteoporosis and if osteoporosis risks are reduced with lifestyle changes. Providing evidence of an association between past physical activity and osteoporosis supports public health policy and health improvement and provides the population with affirmative actions that can prevent or reduce the likelihood of developing osteoporosis.

3.1 STUDY SAMPLE

In 1972, the Rancho Bernardo (RB) Heart and Chronic Disease Study was established at the University of California San Diego School Of Medicine, to evaluate heart disease risk factors. All residents in the Rancho Bernardo, California, community were invited to participate with free examinations. This ongoing longevity study has consisted of 10 periodic visits, with the most recent visit in 2003-2006. Between February 1988 and February 1992, surviving community-dwelling residents aged 55 years or older (typically with a birth year of 1922 or earlier) were invited to participate in a study of osteoporosis of which 80 percent of eligible participants agreed. The current analysis uses RB visit 5 and is restricted to persons aged 55 -90 years of age \( n = 1,682 \).

Participants received an extensive evaluation regarding osteoporosis. Data collected included extensive self-administered forms about personal and family medical history, reproductive history, lifetime exercise, smoking, current medication, and vitamin use (all pills and prescriptions were brought to the study center for confirmation of current medication use), blood pressure, height and weight (measured with the participant wearing light clothing without shoes). Body mass index was calculated with weight/height. Information about the sites of bone fractures, age at the time of each fracture, and the level of distress associated with any fracture was documented in detail. Fractures of the spine, hip, wrist, and clavicle were confirmed by a medical chart review.
3.2 Sample Characteristics

Of the 1,682 Rancho Bernardo Visit V participants, 688 were male (40.9%) and 994 (59.1%) were female. All participants were between 55 - 90 years old. Fifty-four cases were removed because of missing data and 1,628 cases were clinically used for statistical analysis.

The “current” group consists of physical activity patterns within the last year that participants were engaged in at the time of the survey. Ages were recoded into three age groups: age group one is comprised of ages 55 - 70 years and has 39.6% participants; age group two is comprised of ages 71 - 80 years and has 35.9% participants; and age group three is comprised of ages 81 - 90 years and has 24.6% participants. In ages 55-70, 54% participants fall into the normal BMD range, whereas 41.6% fall into the osteopenia range of -1 to -2.5, and 4.4% fall into the osteoporosis range of -2.5 or less. In age group 71- 80, 34.4% participants fall into the normal BMD level, whereas 47.8% fall into the osteopenia range of -1 to -2.5, and 17.7% fall into the osteoporosis range of -2.5 or less. In ages 81 – 90, 22% participants fall into the normal BMD level, 46.9% fall into the osteopenia range of -1 to -2.5, and 17.7% fall into the osteoporosis range of -2.5 or less.

3.3 Physical Activity

The Rancho Bernardo Study obtained former and current exercise information for the survey (Greendale et al., 1995). The survey asked participants whether they usually engaged in strenuous exercise, moderate exercise, or mild exercise for at least 15 minutes per session. Participants were asked to recall usual exercise habits during their teenage years, at 30 years of age, 50 years of age. Subjects were asked to report their usual pattern during the last year to estimate current exercise. They were also asked how many times within a week during leisure time do they currently engage in regular activity long enough to work up a sweat. Physical activity level is categorized as mild, moderate, or vigorous. Mild exercise (minimal effort) examples are: yoga, archery, fishing from river bank, bowling, horseshoes, golf, snowmobiling, and easy walking. Moderate exercise (not exhausting) examples are: fast walking, baseball, tennis, easy bicycling, volleyball, badminton, easy swimming, alpine skiing, and popular or folk dancing. Strenuous exercise (heart beats rapidly) examples are: running, jogging, hockey, football, soccer, squash, basketball, cross country skiing, judo, roller skating, vigorous swimming, and vigorous long distance bicycling.
For the analysis of this study (based on physical activity responses) age groups 30s and 50s are combined and past physical activity was defined as: moderate or vigorous physical activity, 5 times or more per week.

3.4 Bone Mineral Density (BMD)

Osteoporosis is diagnosed using a bone mineral density (BMD) test, a safe and painless way to detect low bone density. Dual energy X-ray absorptiometry (DXA or DEXA) scans are used to measure total body composition and fat content with a high degree of accuracy (comparable to hydrostatic weighing) as a diagnostic measure. DXA estimates three body sections consisting of lean body mass, fat mass, and bone mass. DXA systems use a source that draws on two X-ray beams with differing energy levels which are aimed at the patient's bones. The differential attenuation of the two energies is used to estimate the bone mineral content. BMD can be determined from the absorption of each beam by bone. Body mass index refers to fat mass and lean body mass, whereas this study is focused on bone mass referred to as BMD and will refer to the X-ray as the DXA. The DXA scan is typically used to diagnose and follow osteoporosis and is used as the reference standard for body composition. DXA is the most thoroughly studied bone density analysis and considered the gold standard in research studies. DXA is, by far, the most widely used technique for bone measurements, since it is considered easy to use, accessible, cheap, and able to provide an accurate estimation of bone mineral density in adults (Gilsanz, 1998).

In terms of measuring bone mineral density, normative databases have largely focused on postmenopausal white women, and these values cannot necessarily be extrapolated to either men or to different races. DXA determinations of bone mineral density are primarily used for fracture risk assessment in postmenopausal women and to select candidates for various pharmacological therapies to reduce fracture risk. The World Health Organization has defined the following categories based on bone density in health white women with an approximate age of 30 years. The T-score is a measurement of the bone density in the hip and spine. The following categories are used in assessing T-scores.

- **Normal bone score:** T-score greater than -1
  If a T-score is between +1 and -1, the bone density is similar to the bone density of a healthy 30-year-old.
• **Osteopenia bone score: T-score between -1 and -2.5**
  If a T-score is between -1.0 and -2.5, typically, the bone density in the hip and spine is below normal and there is low bone density, or osteopenia.

• **Osteoporosis bone score: T-score less than -2.5**
  If a T-score is below -2.5 it generally means that there is severe bone loss which causes bones to become weak and fracture or there is established osteoporosis. The lower the score, the lower the bone mass with greater risk of fracture.

### 3.5 Statistical Analysis

Descriptive statistics and frequencies were used to describe sample characteristics in terms of age, gender, physical activity and osteoporosis status (normal, osteopenia, and osteoporosis). To test unadjusted associations of demographic variables, physical activity with osteoporosis status, Chi-square analyses were conducted.

Multiple logistic regression was conducted to evaluate adjusted effect of past physical activity on laser osteoporosis status, after controlling for demographic factors and risk behaviors (age, gender, and risk variables).
CHAPTER 4

RESULTS

4.1 PATTERN OF HISTORICAL PHYSICAL ACTIVITY

During teenage years, 487 participants engaged in mild physical activity five times a week or more (5+), 715 participants engaged in moderate physical activity 5+, and 574 participants engaged in vigorous physical activity 5+. During age 30, 350 participants engaged in mild physical activity 5+, 311 participants engaged in moderate physical activity 5+, and 150 participants engaged in vigorous physical activity 5+. During age 50, 385 participants engaged in mild physical activity 5+, 284 participants engaged in moderate physical activity 5+, and 89 participants engaged in vigorous physical activity 5+. There were 439 participants that “currently” engaged in mild physical activity 5+ (within the last year), 283 participants engaged in moderate physical activity 5+, and 29 participants engaged in vigorous physical activity 5+. Participants may have engaged in physical activity in more than one category.

According to Table 4.1, within physical activity at least five times a week, all three levels of physical activity (mild, moderate, and vigorous) decreased at age 30 from teenage years. The greatest decrease noted is in the vigorous level from 34.1% of teenage engaging in vigorous physical activity to 8.9% of the 30s group engaging in such activity. There was a similar decrease in the moderate level from 42.5% to 18.5%, and a decrease from 29.0% to 20.8% in the mild level of physical activity. From age 30 to 50 there was an increase in mild activity from 20.8% to 22.9%. Both the moderate and vigorous activity levels decreased from 18.5% to 16.9% and from 8.9% to 5.3% respectively. Within participants who currently exercise, mild exercise has increased from 50 years to present age (at time of survey) from 22.9% to 26.1% and slightly decreased from 16.9% to 16.8% in the moderate level of physical activity and from 5.3% to 1.7% in the vigorous level of physical activity. This suggests that persons who engaged in mild physical activity during teenage years progressively were more likely to increase their physical activity from age 30 to present,
### Table 4.1. Pattern of Historical Physical Activity

<table>
<thead>
<tr>
<th>Age</th>
<th>Physical Activity*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mild</td>
</tr>
<tr>
<td>Teenage</td>
<td>487</td>
</tr>
<tr>
<td>30s</td>
<td>350</td>
</tr>
<tr>
<td>50s</td>
<td>385</td>
</tr>
<tr>
<td>Current**</td>
<td>439</td>
</tr>
</tbody>
</table>

*participants may be in more than one category at a time

**current activity within the last year (at time of survey)

whereas, moderate and vigorous levels of physical activity decrease if engaged in teenage years.

### 4.2 Simple Association between Demographic Characteristics and Osteoporosis

Results in Table 4.2 show that the proportion of people with normal BMD (range of -1 and higher) drops significantly as people age; from age group 55-70 to age group 71-80 (53.9% to 34.3%) and from age group 71-80 to age group 81-90 (34.3% to 21.9%). The proportion of people with osteopenia (BMD range of -1 to -2.5) also increased with older age; from age group 55-70 (41.7% to 47.5%) at age group 71-80 and slightly decreased at age group 81-90 to 46.7%. Last, the people with osteoporosis (BMD range -2.5 and below) level also increased with age from age group 55-70 at 4.3% to age group 71-80 at 18.2% and increased significantly again at age group 81-90 at 31.4%. See Table 4.2. Unadjusted association between age and osteoporosis status was found to be significant based on Pearson Chi-Square analysis results ($\chi^2 = 187.8; p = .000$), indicating that older age is associated with the likelihood of developing osteoporosis.
Table 4.2. Simple Association between Demographic Characteristics and Osteoporosis

<table>
<thead>
<tr>
<th>Status</th>
<th>Age</th>
<th>Frequency</th>
<th>Percent</th>
<th>Value</th>
<th>df</th>
<th>Pvalue</th>
<th>OR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal BMD</td>
<td>55-70</td>
<td>349</td>
<td>21.44</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>71-80</td>
<td>202</td>
<td>12.41</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>81-90</td>
<td>86</td>
<td>5.28</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Osteoporosis</td>
<td>55-70</td>
<td>298</td>
<td>18.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>71-80</td>
<td>387</td>
<td>23.77</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>81-90</td>
<td>306</td>
<td>18.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1628</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Missing data = 54 from original data set of 1682

Of the 1682 participants 41% were male and 51% were female. Within the 41% male group 20.4% fell within the normal BMD range, 16.3% within the osteopenia range, and 4.2% within the osteoporosis range. Within the 59% female, 18.8% fell within the normal range, 28.8% within the osteopenia range, and 11.4% within the osteoporosis range of BMD. Women showed lower rates of normal BMD levels than men (20.4% versus 18.8% respectively). However, men showed lower proportions of osteopenia (16.3% versus 28.8%) and osteoporosis (4.2% versus 11.4%) than did women ($\chi^2 = 58.8; p = .000$). This suggests that women have lower normal rates of BMD, higher rates of osteopenia, and higher rates of osteoporosis than do men.
4.3 Simple Association Between Past Physical Activity and Osteoporosis

Almost 47% participants at 30 years of age who engaged in either moderate or vigorous physical activity at least 5 times a week had normal BMD compared to 37.3% who did not engage in moderate or vigorous physical activity. The proportion of osteopenia is lower among participants who engaged in moderate or vigorous physical activity (42.0%) when compared to that of those who do not (46.0%). Likewise, the proportion of osteoporosis among participants (11.3%) who engaged in moderate or vigorous physical activity 5 times a week or more was less than that among those who did not engage in physical activity (16.8%; $\chi^2 = 12.2; p= .002$). Thus, results suggested that past physical activity at age 30s was associated with a lower proportion of osteoporosis.

Similarly, almost 45% of participants at 50 years of age who participate in moderate or vigorous physical activity at least 5 times a week have normal BMD compared to about 38% who do not engaged in physical activity. The proportion of osteopenia is slightly lower among participants who engaged in moderate or vigorous physical activity at age 50s (45.5%) when compared to those that did not (46.0%). A smaller proportion of participants (11.1%) who engaged in moderate or vigorous physical activity at least 5 times weekly had osteoporosis when compared to those who did not (16.7%; $\chi^2 = 8.4; p= .014$). Results suggest that moderate or vigorous physical activity at 50 years of age was associated with higher rates of normal BMD and lower rates of osteopenia and osteoporosis.

Similarly, the same associations were found between past physical activity and osteoporosis status. Past physical activity at moderate or vigorous intensity, 5 times or more a week was associated with higher normal BMD (46.5% vs. 36.4%), lower osteopenia (42.8% vs. 46.1%), and lower osteoporosis (10.8% vs. 17.6%; $\chi^2 = 19.1; p= .000$). Results suggest that individuals who engage in moderate or vigorous physical activity during their 30s and 50s have higher rates of normal BMD than those who did not. So, for the sake of analysis, age 30s and age 50s will be grouped together.

Participants who currently engage in moderate or vigorous physical activity at least 5 times a week are also grouped together. Over 48% of this group falls into the normal BMD level compared to 37.3% that do not engage in moderate or vigorous physical activity. The risk of osteopenia is lower among participants who engage in moderate or vigorous physical activity at least 5 times a week or more.
activity (41.5%) when compared to those who do not (45.9%). A significantly smaller proportion of participants (10.1%) who engaged in moderate or vigorous physical activity fall into the osteoporosis level when compared to those who did not (16.8 %) ($\chi^2 = 15.2; p= .000$). Results suggest that individuals who currently engaged in moderate or vigorous physical activity at least 5 times weekly had higher rates of normal BMD than those who did not.

### 4.4 Multiple Regression Results

To investigate adjusted association between past physical activity (focused on moderate or vigorous, 5 times or more) and osteoporosis among older population, multiple logistic regression was conducted. Demographic variables such as age and gender, clinical risk factors such as history of fallen and fracture, and behavioral risk factors such as drinking and smoking were controlled. After controlling for risk factors in the logistic regression model of this study, older people who had past (combining ages of 30s and 50s) moderate or vigorous physical activity at least 5 times a week were 0.627 times as likely to develop osteoporosis than people who do not engage in moderate or vigorous physical activity (OR=0.627; 95% CI: 0.465~ 0.845). Table 4.3 shows demographic, clinical, and behavioral characteristics.

**Demographic risk factors:** After controlling for other variables in the logistic regression model, people in their 71-80 years of age were 0.200 times as likely to develop osteoporosis than people in their 55-70 (OR= 0.200; 95% CI: 0.124~0.321) and people in their 81-90 years of age were 0.481 times as likely to develop osteoporosis than those who were in their 55-70 (OR= 0.481; 95% CI: 0.291~0.794) years of age. Findings suggest that the odds of osteoporosis is lower among males who engaged in moderate or vigorous physical activity than for females and for the 81-90 age group of both sexes who engaged in moderate or vigorous physical activity. Males who engaged in moderate or vigorous physical activity were 0.529 times as likely to develop osteoporosis as females or both sexes age 81-90 who engaged in moderate or vigorous physical activity (OR= 0.529; 95% CI: 0.392~0.713).
Table 4.3. Multiple Regressions

Adjusted Demographic Multiple Regression

(n = 1682)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Groups</th>
<th>OR</th>
<th>Lower</th>
<th>Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td>0.529</td>
<td>0.392</td>
<td>0.713</td>
</tr>
<tr>
<td>Age</td>
<td>55-70</td>
<td>reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>71-80</td>
<td>0.200</td>
<td>0.124</td>
<td>0.321</td>
</tr>
<tr>
<td></td>
<td>81-90</td>
<td>0.481</td>
<td>0.291</td>
<td>0.794</td>
</tr>
<tr>
<td>PA30505*</td>
<td></td>
<td>0.627</td>
<td>0.465</td>
<td>0.845</td>
</tr>
<tr>
<td>Fracture(s)**</td>
<td></td>
<td>0.535</td>
<td>0.372</td>
<td>0.771</td>
</tr>
<tr>
<td>Fallen ***</td>
<td></td>
<td>0.924</td>
<td>0.643</td>
<td>1.328</td>
</tr>
<tr>
<td>Smoking****</td>
<td>Never</td>
<td>reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Past</td>
<td>0.388</td>
<td>0.212</td>
<td>0.709</td>
</tr>
<tr>
<td></td>
<td>Currently</td>
<td>0.462</td>
<td>0.256</td>
<td>0.833</td>
</tr>
<tr>
<td>Alcohol*****</td>
<td>V8</td>
<td>Never</td>
<td>reference</td>
<td></td>
</tr>
<tr>
<td></td>
<td>V6</td>
<td>1 time</td>
<td>1.585</td>
<td>0.774</td>
</tr>
<tr>
<td></td>
<td>V5</td>
<td>2-3 times</td>
<td>1.161</td>
<td>0.680</td>
</tr>
<tr>
<td></td>
<td>V4</td>
<td>1-2 days a week</td>
<td>1.165</td>
<td>0.676</td>
</tr>
<tr>
<td></td>
<td>V3</td>
<td>3-4 days a week</td>
<td>0.945</td>
<td>0.552</td>
</tr>
<tr>
<td></td>
<td>V2</td>
<td>5-6 days a week</td>
<td>0.951</td>
<td>0.527</td>
</tr>
</tbody>
</table>

(table continues)
Table 4.3. (continued)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Groups</th>
<th>OR</th>
<th>Lower</th>
<th>Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>V1</td>
<td>everyday</td>
<td>0.809</td>
<td>0.534</td>
<td>1.226</td>
</tr>
</tbody>
</table>

* Moderate or Vigorous physical activity during 30s & 50s at least 5 times a week
** Age 45 and older
*** Within the last 12 months
**** Past = at least 100 cigarettes in lifetime
***** Variable V8-V1 excluding V8 and within last 30 days

Clinical risk factors: Results supported an insignificant association that people who had fallen within the past 12 months were 0.924 times as likely to develop osteoporosis as people who had not fallen within the past 12 months (OR= 0.924; 95% CI: 0.643~1.328). Findings suggest that people who had self-reported fracture(s) (at any site age 45 or older) were 0.535 times as likely to develop osteoporosis than people who reported having no fracture(s) (OR= .535; 95% CI: 0.372~0.771).

Behavioral risk factors: Results suggest that people who have smoked at least 100 cigarettes in the past were 0.388 times as likely to develop osteoporosis than people who have never smoked cigarettes (OR = 0.388; 95% CI: 0.256 ~ 0.833) and people who currently smoked cigarettes were 0.462 times as likely to develop osteoporosis than people who have never smoked cigarettes (OR = 0.462; 95% CI: 0.256 ~ 0.833). All findings for alcohol use showed insignificant results, however, questions only asked about alcohol consumption within the last 30 days.

In conclusion, age, being female, history of smoking, history of fracture(s) over age 45, and physical inactivity, had significant associations with increased risk of osteoporosis. However, falls within the last year and drinking within the last month were insignificant.
CHAPTER 5

DISCUSSION

Empirical tests conducted for the present study indicated that moderate or vigorous levels of activity at least 5 times per week significantly decreased the likelihood of osteoporosis in the aging population. These findings support the concept that sustained physical activity is important. From the perspective of feasibility of physical activity recommendations, the findings in the present study are congruent with the Center for Disease Control’s recommendation of 30 minutes of daily exercise 5 times week.

With respect to activity level, the present study shows moderate or vigorous physical activity at least five times a week at age 30s - 50s significantly increases BMD and is beneficial to bone health. These results are consistent with the Rancho Bernardo Study findings that bone densities of strenuous and moderate exercisers were higher than those of mild or less than mild exercisers (Greendale et al., 1995). The greatest benefit accrues to participants who engaged in physical activity during their 30s - 50s and who were currently exercising (at time of survey), which also is consistent with the Rancho Bernardo Study, which shows a positive association between moderate and vigorous physical activity and within lifetime exercise (Greendale et al., 1995). Ulrich et al. (1999) study is also in alignment with the present study results and concluded that lifetime mild household and occupational (minimum to moderate) physical activity is associated with bone mineral density in pre-menopausal women. These data suggest a protective effect of lifelong exercise on BMD.

In the present study, multiple regression results showed that people who had past moderate or vigorous physical activity at least 5 times a week have a 0.627 times the likelihood of developing osteoporosis as people who do not engage in moderate or vigorous physical activity at least 5 times weekly. Because females have a higher likelihood of developing osteoporosis than males, this should be of interest to policy makers in recommending early and routine bone screening services for women. Currently, the U.S. Preventive Services Task Force recommends BMD screening in all women older than 65
years and for those older than 60 years at high risk (WHO, 2003). Likewise, because age is a significant predictive factor in developing osteoporosis, policy makers should consider this factor also.

Regression analysis shows a strong association between smoking and osteoporosis. However, the questions asked were: “do you smoke?”; “have you smoked more than 100 cigarettes?” and, “do you currently smoke?” The longevity of the study, and the fact that smoking more than 100 cigarettes is a vague question, leaves this variable open for controversy. However, this may be indicative of behavioral activities throughout adulthood. Smoking was first identified as a risk factor for osteoporosis more than 20 years ago (Eustice, 2006). Current studies have shown a direct relationship between tobacco use and decreased bone density. Analyzing what impact cigarette smoking has on bone health is difficult. It is complicated in determining whether a decrease in bone density is due to smoking itself or to another risk. Women who smoke also may have an earlier menopause than nonsmokers. Smokers tend to drink more alcohol, and may be less physically active (Eustice, 2006).

Additionally, many studies on the effects of smoking claim that smoking plus alcohol use increases the risk of fractures. Although this study showed no association between drinking and osteoporosis, the questions asked about drinking were “within the last month only”. This behavior, similar to smoking, could also be indicative of past behavioral patterns with like consequences. Additionally, many studies on the effects of smoking claim that smoking increases the risk of osteoporotic fractures (Eustice, 2006).

The findings for the variable “fracture(s) at age 45 or older” are significant (p = .001). Literature shows a protective effect of exercise and mild to moderate physical activity against hip fracture in case-control studies. The present study is in alignment with Moayyeri’s (2008) study with hip fracture claims that moderate physical activity is associated with a hip fracture risk reduction. These results also support Jaglal et al. (2000) study that recent moderate physical activity protected against fractures, especially hip fractures. In the United States, the percentage of fractures with a root cause of osteoporosis is alarming. According to the World Health Organization, the lifetime risk of hip fractures is 17.5% for U.S. women, and the mortality rate is 24% for hip fractures within one year. For women older than 65 years, the age-adjusted mortality rate for vertebral compression fractures is 23% (WHO, 2003).
The findings for the variable “have you fallen within the last year” were not significant in the present study (p = .213) in mild physical activity (including walking) even if it was 5 times a week or more. There are contributing benefits of mild physical activity such as walking. Cummings and Melton’s (2002) study showed that walking had protective measures on osteoporotic bone fractures. This supports the Greendale et al., (1995) study that demonstrated a borderline-significant association (p = 0.06) with spine BMD and mild activity such as walking. These findings are valuable for taking preventive measures against osteoporosis. Changes in balance and physical performance are associated with osteoporosis, which can have psychosocial consequences, therefore increasing the risk of falling (Smulders, Van Lankveld, Laan, Duysens, & Weerdesteyn, 2011). Most falls occur during walking (Smulders et al., 2011). Further research on the association of falls and osteoporosis should be studied. These findings, in addition to similar studies, contribute to the body of knowledge that may have beneficial implications for policymaker’s recommendations, continuing education, and health promotion.

The use of both technological tools (DXA) for BMD measurement and self-reported measures of physical activity strengthens the study. Self-reported physical activity level measurements allowed participant perceptions therefore, physical activity recall may contain recall bias. Technological tools are valid objective indicators of BMD. The study sample was white, fairly well educated, and participants were somewhat equally affluent, which limits the generalizability of findings. All participants had equal access to environmental features to facilitate physical activity.

Many studies are available regarding the treatment of diagnosed osteoporosis and physical activity; however, the present study addresses concerns with physical activity levels prior to any treatment of osteoporosis. Osteoporosis typically materializes at an older age; although, there are a significant number of younger economically active people who suffer from the disease. This type of osteoporosis results from extended use of medications such as glucocorticoids, when the disease is called steroid- or glucocorticoid- induced osteoporosis, or other chronic predisposing medical problems or disease. Consequently, society’s labor force affected by osteoporosis has pecuniary implications as well (International Osteoporosis Foundation [IOF], 2010). Though osteoporosis in the younger population is of concern this study focuses on preventive strategies through physical activity to decrease the likelihood of
osteoporosis in the aging population. Further studies should investigate the effect on physical activity: in the treatment of osteoporosis, in younger populations, and during teenage and future chronic illness. This information may be beneficial to policy makers for standardized physical education requirements during school years.
REFERENCES


