EVALUATION OF CURRENT DECISION RULES AND HEALTHCARE PROFESSIONAL PRACTICES FOR DECTECTING OSTEOPOROSIS RISK IN THE YOUNG ADULT POPULATION

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Abstract

Evaluation of current decision rules and healthcare professional practices for detecting osteoporosis risk in the young adult population
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Osteoporosis is caused by a multitude of factors. An individual's risk for experiencing a bone fracture as a senior citizen increases without early intervention. Healthcare professionals do not have access to validated survey tools to identify young adults in need of osteoporosis prevention education, although survey tools to identify postmenopausal women at high risk for low bone mass are available. The purposes of this study were to evaluate three of these survey tools for use in a younger population, and to determine if young adults with osteoporosis risk factors received bone health education from a health professional. Forty-two men and 41 women completed surveys and health questionnaires; responses were compared to bone mineral density (BMD) and content (BMC) measurements. Healthcare professionals discussed bone health with only 13% of participants. Chi-square analysis revealed that health professionals were not more likely to discuss osteoporosis with subjects based on age or gender. Participants with T-scores ≤ -1.0 were not more likely to receive bone health education. Area under the receiving operating characteristic (AUROC) curves analysis revealed that no survey tools were able to identify moderate-risk participants at T-scores ≤ -1.0, and AUROC curves for all surveys did not exceed 0.525 at this level. Two surveys detected participants at high risk for bone disease with identical AUROC curves of 0.821 at a T-score ≤ -2.0, and 0.813 at a T-score ≤ -2.5. The AUROC curves indicate that current tools designed for older women do not detect young adults with moderately low T-scores.

DEDICATION

This thesis is dedicated to my parents, Kenny and Ann, who have made every possible sacrifice in their lives to enable me to reach my goals; and to my husband, James, for providing countless hours of love, support and laughter throughout this entire process.

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CHAPTER 1

Introduction

Osteoporosis is a debilitating bone disease that can be caused by a multitude of lifestyle and metabolic factors ("Assessment of fracture risk…" 1994). If maximum bone density is not reached and maintained during adolescence and early adulthood, an individual's risk for experiencing a bone fracture as a senior citizen increases (Looker et al. 1997). These resulting fractures and other osteoporosis-related care costs the healthcare system $13.8 - 20 billion in hospitalizations, therapies, treatments, nursing home stays, and lost work productivity (Ray et al. 1997). In addition, mortality in both men and women who sustain a hip fracture is significantly increased both during the hospital stay and one year after hospital discharge (Center et al. 1999, Forsen et al. 1999, Kiebzak 2002, National Osteoporosis Foundation 1998). Bone fracture survivors often experience a significant decline in quality of life, and many elderly citizens express significant anxiety over the possibility of fracture occurrence (Salkeld et al., 2000).

At the present time, it is questionable whether medications designed to prevent osteoporosis-related fractures are cost-effective ("Analysis of the effectiveness…" 1998); therefore, prevention remains the best option for osteoporosis treatment. Most individuals reach peak bone mass, or the maximum bone mass attainable for an individual, by their late twenties (Anderson 2000, Recker et al. 1992). Prior to this time, continued bone growth is possible. Although heredity, gender and ethnicity each play a role in peak bone mass, epidemiological studies suggest that diet and environment also play critical roles in bone development and maintenance throughout the lifecycle (Anderson & Pollitzer 1994, Johnston et al. 1992, Lees et al. 1993, Mazess 1982, Runyan et al. 2003). This would

suggest the need for preventive education with a young adult population.

Currently, no strict guidelines exist to aid physicians in detecting those persons at risk for osteoporosis; however, general guidelines and screening tools have been developed for this purpose ("Assessment of fracture risk…" 1994, National Osteoporosis Foundation 1998, "Position of the American…" 1999). Multiple studies indicate that healthcare professionals do not discuss osteoporosis with patients of all ages, and often do not treat those patients already diagnosed with the condition (Kiebzak et al. 2002, Mudano et al. 2003, Schrager et al. 1999). Survey tools that allow health professionals to screen patients for low bone density risk could provide efficient, cost-effective care in both the clinical and public health settings. While multiple tools have been validated in an older cohort (Cadarette et al. 2000, Cadarette et al. 2001, Lydick et al. 1998, National Osteoporosis Foundation 1998, Weinstein & Ullery 2000), no surveys are validated in a younger cohort of men and women. Physicians often have only a limited time available during patient visits, and must prioritize health concerns to discuss with each individual. Given the wealth of information suggesting that peak bone mass is achieved early in life and that the best osteoporosis treatment is prevention, these surveys could provide a way to educate both physicians and consumers about the importance of bone building and maintenance in young, premenopausal women and in young men and identify those patients who can most benefit from such a discussion.

In order to provide information in these areas, the current study was designed to: (1) determine whether currently existing survey tools designed to detect osteoporosis risk in postmenopausal females are also applicable to a younger adult population, and to (2)

determine if those adults with risk factors for osteoporosis have been informed of having a high-risk status by any healthcare professional. This study found that health professionals discuss bone health with consumers less than 50% of the time; moreover, gender, age and actual bone density results did not affect the rates of discussion of osteoporosis among health professionals and their clients. Current survey tools in use for the older population are not appropriate to screen men and women ages 20-40 years for osteoporosis risk. These results indicate the need for additional training among health professionals regarding osteoporosis prevention, and warrant the development and validation of a survey tool capable of screening the young adult population for osteoporosis risk.

CHAPTER 2

Review of Literature

Statement of the Problem

Research concerning the prevalence of low bone mineral density (BMD) in young adults is limited. Currently, healthcare professionals do not have access to validated survey tools that could identify young adults in need of osteoporosis prevention education. This study evaluates the effectiveness of three survey methods in detecting those adult men and women with low bone mass.

Osteoporosis

Osteoporosis is a skeletal disease manifested by significantly low bone mass that increases an individual's fracture risk ("Assessment of fracture risk…" 1994). It is prevalent primarily in developed countries and is one of the most debilitating diseases in regards to quality of life (Anderson 2000, Trowell & Burkitt 1981). Osteopenia is characterized by low bone mass that does not meet the accepted criteria for the diagnosis of osteoporosis, but which is a potential precursor for osteoporosis. According to the World Health Organization (WHO), an individual's fracture risk is elevated for each standard deviation (SD) below the average peak bone mass for young, healthy adults. Bone mineral density testing is usually used as a predictor of osteoporosis. Osteopenia occurs when BMD is between 1 and 2.5 SD below the young adult reference mean. Osteoporosis is diagnosed if BMD is 2.5 SD or greater below the young adult reference mean ("Assessment of fracture risk…" 1994). After BMD has been considered, age is the next best predictor of fracture risk (Kanis et al. 2000).

Prevalence

Both men and women have an increased risk of developing osteoporosis as they progress through the lifecycle, with an estimated 30 million Americans currently diagnosed with osteopenia or osteoporosis (National Osteoporosis Foundation 1998, "Position of the American…" 1999). Osteoporosis increases the risk of bone fracture as an individual ages. The probability that a woman will develop an osteoporotic bone fracture during her lifetime is 50%. In comparison, men have a 13 – 25% lifetime fracture risk (Looker et al. 1997). Yet, those individuals who do develop the disease place a significant burden on the healthcare system. Osteoporosis-related healthcare accounts for approximately 2.5 million physician visits, 432,000 hospital admissions, and 180,000 nursing home placements annually. Expected survival rates for men and women are reduced by 15 – 20% during the year following a hip fracture (Center et al. 1999, National Osteoporosis Foundation 1998). While more hip fractures occur in women, men are twice as likely to die during hospital admission for a hip fracture, and have a 14% higher mortality rate one year after fracture occurrence (Forsen et al. 1999, Kiebzak 2002). The decline in quality of life associated with a fracture can also contribute to increased anxiety and depression in women. In a survey of 194 women over 75 years of age, 80% indicated that they would rather die than experience a hip fracture and subsequent nursing home admission with decreased independence (Salkeld et al 2000).

Economic Cost

Osteoporotic fractures contribute significantly to current medical care costs. The treatment of fractures in the United States costs approximately $13.8 – 20 billion annually, with the majority of expenses dedicated to inpatient medical services and

nursing home placements (Pramer et al. 1992, Ray et al. 1997). These expenses could increase exponentially with the expected population growth of elderly persons and reach $50 billion by the year 2040 (Ray et al 1997). Unfortunately, the cost-effectiveness for preventive treatment remains highly controversial. Medications to preserve or build bone mass are used for many years, even while the immediate risk for a fracture is minimal (Kanis et al. 2000). A report from the National Osteoporosis Foundation estimates that the number of women aged 50 years needed for treatment to successfully prevent one hip fracture is approximately 355 ("Analysis of the effectiveness…" 1998). These numbers decrease to 150 women aged 60 years, 55 women aged 70 years, and 20 women aged 80 years ("Analysis of the effectiveness…" 1998). This debate highlights the importance of interventions designed to educate young adult men and premenopausal women on strategies available to reach and maintain peak bone mass.

Peak Bone Mass

Peak bone mass refers to the attainment of maximum bone mass for an individual (Anderson 2000). This state is typically reached by the third decade of life, although the specific age can vary due to individual environmental differences in diet, physical activity levels and strain placed on the skeleton during the early decades of life (Recker et al. 1992). Gender contributes to peak bone mass; women have been found to reach an average BMD level 15% lower than men's peak attainment (Mazess 1982). Researchers have also hypothesized that heredity plays a crucial role in the level of peak BMD attainable, accounting for as much as 70% of acquired bone density (Johnston et al. 1992, Runyan et al. 2003). One study found that the amount of bone mass attained by age twenty varied significantly by ethnicity, with African-American females possessing the

highest levels, followed by Caucasian-Americans and then Japanese (Anderson & Pollitzer 1994).

Hereditary factors for peak bone mass acquisition cannot be ignored; however, despite the role that ethnicity may play in bone development, epidemiological evidence has been presented that suggests that environmental factors play a significant role in inadequate peak bone mass attainment in the western world. Japanese and Chinese women typically have lower BMD than their American counterparts, yet Americans are twice as likely to experience hip fracture compared to Japanese women and have an overall fracture risk five times higher than Chinese women (Anderson & Pollitzer 1994, Campbell & Cox 1996, Fujita & Fukase 1992). Anthropological findings indicated that the bones of 87 British females buried prior to the year 1900 maintained superior bone density levels in life compared to 300 present-day female counterparts (Lees et al 1993). In order to understand how environmental factors could influence bone development and how best to provide prevention strategies to achieve maximum peak bone mass, a clear understanding of bone formation and resorption is necessary.

Bone Structure

Bone tissue is essential for humans to provide a supportive framework for the body. The tissue is an organic matrix composed primarily of type I collagen fibers interspersed with deposits of phosphate and calcium salts, and hydroxyapatite crystals (Anderson 2000). The tensile properties of collagen fibers provide bone with flexibility, while the hardness of hydroxyapatite crystals provides bone with strength. Bone is comprised of two types of tissue: cortical and trabecular. Eighty percent of the human skeleton is comprised of cortical, or compact, bone, which is located primarily in the

shafts of long bones (Anderson 2000). The remaining 20% consists of trabecular bone, also called cancellous or spongy bone due to its bony interconnecting structure that resembles a sponge. This structure is less dense than that of cortical bone, and provides a larger surface area that can be exposed to circulating fluids within the marrow. As a result of this structure, trabecular bone, which is located in the ends of long bones, wrists, vertebrae, hips, and scapulas, is more susceptible to the lack of nutrients and hormones as a person ages, and is responsible for the majority of fractures in the elderly (Anderson 2000).

Bone Resorption

Bone undergoes a remodeling process in which tissue is continuously resorbed and formed to grow, repair, and adapt to new external strains placed on the skeleton (Anderson 2000). Current research indicates that approximately 20% of trabecular bone is continually in the remodeling process (Raff & Shaker 2003). Three types of cells are primarily responsible for bone formation and resorption. Osteocytes actually begin as osteoblast cells, but become calcified as they are trapped within the forming protein matrix and are eventually buried deep within the mineralized bone. These cells continue to communicate with other bone cells to encourage the formation and resorption process (Anderson 2000). Osteoclasts are primarily responsible for bone resorption. Cytokines such as interleukin-1 activate pre-osteoclastic cells located within bone marrow. These cells migrate to the surface of bone where they mature and secrete enzymes that reduce bone pH and dissolve the mineral components (Anderson 2000). Osteoblasts then form bone through the synthesis of matrix proteins and communication via cytokine secretions that act on osteoclast cells (Anderson 2000).

Bone Formation

Following the resorption of bone tissue, osteoblasts migrate to the exposed area and secrete type I collagen along with other matrix proteins. The collagen polymerizes to form new fibers, where calcium and phosphate salts eventually precipitate and develop into hydroxyapatite crystals (Anderson 2000). Whereas bone resorption can be completed in a few days, formation may take as long as 3 – 6 months, or longer in the elderly (Anderson 2000). Due to calcium homeostasis, young healthy adults have a "zero balance" for bone mass in which overall resorption and formation are equivalent. In elderly individuals and young adults with nutritional or hormonal imbalances, increased trabecular resorption can occur without adequate formation, resulting in poor calcium homeostasis and bone loss (Anderson 2000).

Calcium Homeostasis

Ninety-nine percent of the body's calcium is located within the hydroxyapatite structure of the skeleton; the remaining 1% is used for on-going life processes (Anderson et al. 2000, Volpe 1999, Yucha & Guthrie 2003). The body has a set serum calcium concentration of approximately 10 mg/dl or 2.5 mmol/L (Anderson 2000). Tight control is maintained over this serum calcium concentration, as an elevated level can result in hypercalcemia with symptoms of fatigue, cardiac arrhythmias, nausea, and constipation. In addition, hypercalcemia can contribute to the development of kidney stones when excess calcium carbonate is deposited in the body's soft tissues (Yucha & Guthrie 2003). Conversely, an inadequate serum calcium concentration, or hypocalcemia, promotes increased passage of sodium ions through the cell membrane, resulting in intestinal

cramping and tetany, or painful muscle spasms (Anderson 2000, Yucha & Guthrie 2003). Respiratory failure may also occur with severe hypocalcemia (Yucha & Guthrie 2003).

In order to maintain calcium homeostasis, the body relies on multiple organ systems and hormones (Volpe 1999, Yucha & Guthrie 2003). Homeostasis is aided by parathyroid hormone (PTH) and 1,25-dihydroxyvitamin D, known as calcitrol. These hormones exert influence over the gastrointestinal, renal, and skeletal systems to either increase or decrease the serum calcium concentration. Parathyroid hormone is secreted by the parathyroid glands in response to changes in the extracellular calcium concentration (Yucha & Guthrie 2003). If dietary intake is inadequate to support a normal serum calcium concentration, the body will mobilize calcium ions from bone marrow or from skeletal tissue itself via osteoclasts. Low dietary calcium intake can increase levels of PTH in circulation, which in turn signals osteoclasts to participate in bone resorption to restore the serum calcium concentration (Anderson 2000, Bronner & Stein 1992). Parathyroid hormone also promotes renal reabsorption of calcium into the portal system, thereby decreasing urinary calcium excretion (Yucha & Guthrie 2003).

In the absence of a sub-optimal serum calcium level, PTH will stimulate the production of calcitrol (Anderson 2000). Calcitrol is formed within the kidney using both orally ingested vitamin D and vitamin D3, or cholecalciferol, which is formed by a cascade of metabolic reactions beginning with the exposure of 7-dehydrocholesterol in the skin to ultraviolet radiation (Holick 1996, Yucha & Guthrie 2003). Calcitrol normally acts within the lower half of the small intestine to increase efficiency of calcium absorption if dietary intake is inadequate, while simultaneously stimulating renal reabsorption of calcium (Anderson 2000, Holick 1996, Yucha & Guthrie 2003).

Unfortunately, this system has been found to be less effective in postmenopausal women and cannot provide sufficient calcium to prevent bone resorption from exceeding bone formation in the postmenopausal years (Ebeling et al. 1992).

Conversely, once the body enters a state of hypercalcemia the thyroid gland will secrete calcitonin, a hormone that inhibits osteoclastic cell activity and stimulates increased renal urinary calcium excretion. With calcitonin release, PTH secretion is significantly reduced, which also promotes increased urinary calcium excretion and inhibits bone resorption (Anderson 2000, Yucha & Guthrie 2003). The regulation of the gastrointestinal, renal, and skeletal systems by PTH, calcitrol, and calcitonin allows the body to maintain calcium homeostasis in healthy individuals by adjusting to even minor deviations in nutritional intake and serum calcium concentration. This strict control allows the body to build peak bone mass and works to maintain BMD levels over time, thereby preventing or delaying the onset of primary osteoporosis.

Types of Osteoporosis

Two types of osteoporosis can be diagnosed in the individual: primary or secondary (Anderson 2000). Primary osteoporosis can occur in women who are postmenopausal, or in both sexes along with the aging process. Postmenopausal women experience a decline in estrogen production that contributes to decreased levels of trabecular bone tissue. This decline results in an increased risk of distal radius and vertebral fractures, as well as hip fractures (Anderson 2000, Caplan et al. 1994). Women who have undergone menopause prior to age 45 years are at a significantly higher risk for vertebral fractures (Caplan et al. 1994). It has been proposed that sex hormones also play

a role in the development of osteoporosis in men, with estradiol (estrogen) serving as the primary hormonal control for bone resorption (Falahati-Nini et al. 2000).

Age-related osteoporosis can occur in men and women over 65 years of age (Anderson 2000). The condition is influenced by a Caucasian or Asian ethnicity, an individual's history of smoking, low body weight, physical inactivity, poor dietary habits, and alcohol consumption (Compston 1992). Increased bone resorption and decreased formation is noted in both trabecular and cortical bone, but imbalanced bone remodeling primarily affects trabecular bone, leading to an increased number of hip and vertebral fractures. These fractures can occur as a result of trauma from a fall or from attempted completion of activities of daily living (ADL) (Anderson 2000).

Secondary osteoporosis occurs when low bone mineral density is present due to the use of certain medications or presence of disease (Anderson 2000, Baillie et al. 1992, Caplan et al. 1994, Mondy et al. 2003). Epidemiological studies indicate that as many as 54% of men and 30% of women with vertebral fractures have secondary osteoporosis as a cause, although osteoporosis itself may never have been diagnosed (Baillie et al. 1992, Caplan et al. 1994). Diseases and medications that have been shown to contribute to low BMD are included in Table 1 (Anderson 2000, Harrison et al. 2002, Klaus et al. 2002, Mondy et al. 2003, National Osteoporosis Foundation 1998, Royal College of Physicians 1999). Often, the pathophysiology relating the underlying disease to osteoporosis is poorly defined and available treatments have not been studied in these populations (Harrison et al. 2002, Klaus et al. 2002, Mondy et al. 2003). For example, low BMD has been identified in as many as 46% of human immunodeficiency virus – positive adults (Miller et al. 2002, Mondy et al. 2003). However, research indicates that osteopenia or

Table 1

Risk Factors in Secondary Osteoporosis

Diseases	**Medications**
Addison Disease	Aluminum-containing antacids
Acquired Immune Deficiency Syndrome	Anticoagulants
Chronic Liver Disease	Anticonvulsants
Chronic Obstructive Pulmonary Disease	Corticosteroids (high doses)
Chronic Renal Failure	Lithium
Crohn's Disease (malabsorption disorders)	Thyroxine (high doses)
Diabetes	
Human Immunodeficiency Virus	
Hyperthyroidism	
Hypogonadism	
Prostate Cancer	
Rheumatoid Arthritis	

osteoporosis is caused more by lifestyle factors and the disease process itself than the anti-retroviral medications used to treat this disease (Mondy et al. 2003). Similarly, patients with rheumatoid arthritis and inflammatory bowel disease experience higher rates of osteoporosis than the general population, but etiologies other than nutrient malabsorption, such as medication effects, have not been fully explored (Harrison et al. 2002, Klaus et al. 2002). Clinicians must take care to monitor the lifestyle habits of patients diagnosed with risk factors for secondary osteoporosis and refer these persons for further evaluation if necessary.

Dietary Intake and Bone Mineral Density

Multiple nutrients are essential for the development of adequate BMD. Evidence suggests that dietary intake early in life does affect BMD levels later in life (Kalkwarf et al. 2003, Nowak et al. 2002). Even in studies where heredity is found to play a significant role in bone development, researchers acknowledge that part of this influence is due to lifestyle factors, such as diet and physical activity, which are shared among family members (Runyan et al. 2003). Bonjour and colleagues (1991) observed that when 149 prepubertal girls consumed foods rich in calcium over a 1 – year period, they experienced significantly increased bone mass at the hip and radial sites. When 28 adolescent boys involved in resistance training were provided with three daily servings of either low-fat milk with calcium or juice without calcium, those boys receiving the additional calcium had significantly greater increases in total body BMD than the boys using resistance training alone (Volek et al. 2003). These effects can continue well into adulthood. Data from the Third National Health and Nutrition Examination Survey (NHANES III) reveals that low milk consumption during childhood and adolescence is

associated with a lower peak bone mass and increased fracture risk in adults (Kalkwarf et al. 2003). Unfortunately, adolescent girls tend to consume few dairy products as they age (Nowak et al. 2002, Runyan et al. 2003), and by early adulthood, over 50% of adults consume less than one serving of milk daily (Klesges et al. 1999). Although dairy products that contain calcium and vitamin D are most often promoted as bone building nutrients, various other dietary habits can also affect BMD levels (Macdonald et al. 2004, New et al. 1997). Research indicates that increased fruit and vegetable consumption has a positive effect on bone attainment and maintenance, possibly by contributing to lower urinary calcium excretion and lower PTH levels (Macdonald et al. 2004, New et al. 2000, Tucker et al. 2002, Tylavsky et al. 2004). These studies highlight the importance of bone building activities in youth and early adulthood to prevent or delay the onset of osteoporosis later in life. A review of those nutrients that affect bone development is necessary to comprehend the impact that a healthful diet can have on BMD, regardless of gender or ethnicity.

Calcium and Bone

The human skeleton acts as a repository for approximately 99% of body calcium (Anderson, 2000); thus, calcium acquisition is hypothesized to play an important role in the development and maintenance of bone. As previously discussed, consumption of foods containing calcium is an integral part of reaching peak bone mass (Bonjour et al. 1991, Kalkwarf et al. 2003, Volek et al. 2003). Calcium absorption occurs via active transport in the duodenum (Pansu et al.1983) as calcium ions are transported through calcium channels across the brush border membrane (Bronner 1997). Inside the cell, calcium is bound to calbindin, a calcium-binding protein that is dependent on vitamin D,

and transported to the basolateral cell surface (Bronner & Pansu 1999, Pansu et al. 1983). Here, the calbindin-bound calcium is pumped out of the cell against the electrochemical gradient via an ATP-dependent calcium pump (Bronner & Pansu 1999). Calcium absorption also takes place via passive transport in the ileum and jejunum, with the majority of absorption occurring in the ileum (Bronner & Pansu 1999, Pansu et al. 1983). Approximately 10% or less of calcium is absorbed through active transport in the colon (Bronner & Pansu 1999).

The type of transport utilized is determined primarily by the amount of dietary calcium presented in the intestine. When intake provides at least 800 mg/d of calcium, passive transport is the preferred method of absorption (Pansu et al. 1983), with bioavailability of calcium from individual food sources being inconsequential to absorption (Deroisy et al. 1997). However, if dietary intake falls below 800 mg/d and bioavailability from foods remains low, active transport mechanisms are utilized (Bronner & Pansu 1999).

Calcium bioavailability – the degree to which calcium is available for absorption and use – is impeded with elevated dietary intake of oxalate and dietary fiber (Anderson 2000, Weaver et al. 1991). Foods with superior calcium bioavailability, such as dairy products, broccoli, and soybeans are promoted for consumption (Anderson 2000). Calcium needs are increased during adolescence, old age, and pregnancy compared to adulthood (Food and Nutrition Board 1999, Yasumizu et al. 1998) and adequate intake is necessary for normal absorption via passive transport in the ileum (Bronner & Pansu 1999). Adequate Intake (AI) levels of 1,000 mg/d for men and women ages 20 – 40 years have been established to aid the public in consuming sufficent amounts of calcium

at various stages of the life cycle (Food and Nutrition Board, 1999). Calcium absorption is also enhanced or inhibited by intake of various other nutrients, some of which are discussed below.

Vitamin D and Bone

Adequate calcium absorption is dependent on the presence of vitamin D (Pansu et al. 1983). Vitamin D is required for biosynthesis of calbindin (Perret et al. 1988), which aids calcium absorption via active transport in the intestine (Bronner & Pansu 1999, Holick 1996, Pansu et al. 1983). Studies have shown associations among vitamin D deficiency, hyperparathyroidism, and increased bone resorption in women of all ages (Cheng et al. 2003, Oomes et al. 1995). These findings are particularly relevant for children and young adults who may not achieve optimal peak BMD without adequate vitamin D, regardless of calcium intake.

Although it is possible to obtain vitamin D through both diet and sunlight exposure, many people with inadequate dietary intake do not spend enough time in the sun to compensate for the lack of oral intake (Anderson 2000). Studies conducted among European children and adolescents indicate that large numbers of youth are currently vitamin D deficient (Crocombe & Mughal 2004, Lehtonen – Veromaa et al. 2002). Moreover, elderly persons who do not participate in outdoor activities and have decreased caloric intakes typically do not receive extended sunlight exposure or adequate dietary vitamin D (Anderson 2000), which further inhibits bone maintenance. Increased intake of vitamin D food sources that meets the adequate intake (AI) of 5 ug/d in men and women ages 20 – 40 years is encouraged; however, studies also reveal that combinations

of calcium and vitamin D supplements are also effective in promoting bone health (Anderson 2000, Food and Nutrition Board 1999).

Phosphorous and Bone

Phosphorous is an essential component of the hydroxyapatite crystals that form the main structure of bone (Anderson 2000), and is therefore essential for bone formation and maintenance. Adequate intake for adults age 20 – 40 years is 700 mg/d (Food and Nutrition Board 1999). Low serum phosphate levels can increase urinary calcium excretion and rates of bone resportion (Raisz & Niemann 1969); thus, supplementation along with calcium intake should be considered in persons with hypophosphatemia (Heaney 2004). However, due to the increased consumption of foods such as carbonated beverages and processed foods with high levels of phosphorus and poor calcium availability, overconsumption of phosphorous has become a more critical issue in Western countries (Calvo & Park, 1996). Excess dietary phosphorus above the established upper limit (UL) of 4,000 mg/d interferes with calcium homeostasis by decreasing the ionized calcium concentration in blood, which in turns stimulates PTH secretion and accelerates bone resorption (Anderson 2000, Calvo & Park 1996, Food and Nutrition Board 1999). Care must be taken to balance calcium and phosphorous intakes through the reduction of highly processed foods so as to promote optimal bone growth. Although the current recommended calcium to phosphorous ratio is 1:1, adverse effects on BMD have not been noted with slightly higher phosphorous intakes (Heaney 2004).

Zinc and Bone

Zinc is an additional component of bone structure and is essential for osteoblastic activity (Anderson 2000), with approximately 1.5 – 2.5 grams found in the body (Volpe

1999). Zinc absorption occurs in the small intestine, but can be affected by intake of other dietary components. It is recommended that men ages 20 – 40 years consume 11 mg/d of zinc, while the AI for women of similar age is 8 mg/d. Concurrent intake of dietary protein has been found to enhance zinc absorption (Anderson 2000), whereas elevated intakes of fiber, copper, iron, phytates, and calcium inhibit zinc absorption (Anderson 2000, Wood & Zheng 1997). A diet that meets the recommended intakes for both zinc and calcium can be beneficial for bone health; however, a diet high in zinc and low in calcium has been shown in animals to contribute to compromised bone structure (Kawamura et al. 2000).Therefore, a diet high in zinc should only be considered when dietary calcium levels are adequate.

Magnesium and Bone

Another component of hydroxyapatite is magnesium. Over 50% of the 21 – 28 gm of total body magnesium is located within bone (Wang et al. 1994). While the complete role of this mineral in bone development is not fully understood (Anderson 2000), it is recognized that magnesium aids in the regulation of calcitonin and PTH, thereby influencing calcium homeostasis (Zofkova & Kancheva 1995). Moreover, magnesium absorption occurs in the small intestine via a pathway similar to that of calcium absorption (Anderson 2000), and excessive intake of either nutrient can adversely affect absorption of the other. Rude and colleagues (2004) demonstrated that, in rats, a 10% reduction in dietary magnesium below the nutritional requirement resulted in a 51% reduction of magnesium bone levels. A significant increase in bone resorption was also noted (Rude et al. 2004). As it is possible that as much as 6.9% of the general population (Wang et al. 1994) and 20% of the African-American population (Fox et al.

1999) is hypomagnesemic, this imbalance could impair normal bone development. Although the exact calcium:magnesium ratio needed for optimal bone growth has yet to be determined, it is recognized that magnesium intake in adolescents equivalent to the recommended dietary allowance (RDA) for teenage girls and boys is adequate for proper bone growth regardless of the amount of calcium consumed (Andon et al. 1996). Additionally, adequate Intake levels are established for adults, with recommended consumption at 400 mg/d for men ages 20 – 30 years, 420 mg/d for men ages 31 – 40 years, 310 mg/d for women ages 20 – 30 years, and 320 mg/d for women ages 31 – 40 years (Food and Nutrition Board, 1999).

Sodium, Fat, Protein and Bone

While the intake of minerals that contribute to skeletal structure is crucial for bone health (Anderson 2000, Calvo & Park 1996, Kalkwarf et al. 2003, Volek et al. 2003, Zofkova & Kancheva 1995), additional nutrients also influence the growth and maintenance of bone. Dietary intakes of sodium, fat, and protein in the United States usually exceed recommended levels (Kennedy et al. 1999). Urinary calcium excretion is typically elevated in individuals with high dietary sodium intakes (Jones et al. 1997, Matakovic et al. 1995). Reduction of dietary sodium to less than 2 gm/d along with a diet rich in fruits and vegetables has been shown to reduce rates of bone resorption (Lin et al. 2003, Macdonald et al. 2004) to levels that are equivalent to increasing dietary calcium intake by 891 mg/d (Devine et al. 1995). Furthermore, calcium absorption itself may be inhibited by a high dietary fat intake, as the fat can bind with calcium to form calcium soaps that pass through the body unabsorbed (Bronner & Pansu 1999).

While plausible relationships between sodium and fat intakes and bone resorption have been established (Bronner & Pansu 1999, Jones et al. 1997), research regarding protein intake and bone is inconclusive. A diet high in protein without adequate calcium intake can contribute to increased rates of urinary calcium excretion (Kerstetter & Allen, 1990); however, dietary protein intake at or below the recommended level of 0.8 gm/kg has been associated with decreased intestinal calcium absorption and secondary hyperparathyroidism (Kerstetter et al. 2003). Moreover, inadequate intake of protein and the resulting hypoalbuminemia often seen in young girls and elderly persons highlights the importance of avoiding strict dietary limitations on protein (Anderson 2000).

Fiber and Bone

Currently, the typical American diet falls well below recommended dietary fiber intakes of 38 gm/d for men and 25 gm/d for women (Food and Nutrition Board 2002, Hendricks & Herbold, 1998). Although it is possible for fiber to inhibit intestinal calcium absorption at intakes of 40 – 50 gm or higher, most Americans do not reach this level of consumption (Anderson 2000). Vegans have been observed to obtain higher levels of fiber intake; however, the overall effects of fiber on calcium absorption are minimal and most Americans should be encouraged to increase consumption of fiber-rich foods such as fruit and vegetables (Anderson 2000, Macdonald et al. 2004, Tucker et al. 2002, Tylavsky et al. 2004) for their other nutrients beneficial to skeletal health.

Phytoestrogens and Bone

Evidence suggests that phytoestrogens, such as soy isoflavones, could be bone protective (Anderson 2000). It has been proposed that the Japanese, who consume less dairy calcium than other populations, may decrease bone resorption rates through high

soy intake (Anderson 2000). In addition, postmenopausal women consuming isoflavone supplements exhibited significantly reduced bone resorption compared to similarly – aged controls (Atkinson et al. 2004). These initial results were tempered by research indicating that while improved estrogen levels were observed in women consuming soy and flaxseed-containing foods, these foods did not significantly decrease bone resorption (Brooks et al. 2004). To date, no recommended levels have been established for phytoestrogen intake, and additional research is needed to determine if these foods are in fact beneficial for bone maintenance.

Multiple nutrients play a role in the development and maintenance of bone throughout the life cycle, although the exact roles that many of these nutrients play remain unclear. Consumers who are aware of which foods promote or inhibit bone turnover are much more likely to lower their risks of developing osteoporosis. Unfortunately, as today's society focuses on weight loss through dieting, consumers frequently receive conflicting dietary information from a variety of sources (Nickols-Richardson et al. 2002). Health educators can provide accurate nutritional advice to these consumers and educate them concerning the importance of osteoporosis prevention. It is necessary to measure the current level of bone health knowledge among consumers and health educators, and to relate this knowledge to the actual practices of education and prevention strategies for osteoporosis.

Healthcare Provider and Consumer Awareness of Prevention Strategies

Despite a lack of strict guidelines for BMD testing, physicians and other healthcare professionals do have multiple general guidelines for identifying those persons at risk for primary or secondary osteoporosis and for educating and treating such

individuals ("Assessment of fracture risk…" 1994, National Osteoporosis Foundation 1998, "Position of the American…" 1999). Researchers also continue to develop prevention strategies to use with minority groups who may not have received prior physician follow-up (Larkey et al. 2003, Orces et al. 2003).

Physician Awareness

As osteoporosis places such a significant burden on the healthcare system, one would expect that healthcare professionals are actively identifying those persons that would benefit from preventive treatment. However, recent studies indicate that even after a fracture, elderly persons do not receive adequate dietary recommendations or follow-up treatment for low bone mass (Kiebzak et al. 2002, Miller et al. 2001, Schrager et al. 1999). One chart review revealed that only 35% of women over age 50 years had documented reviews of osteoporosis risk by their physicians in their medical charts (Schrager et al. 1999). Kiebzak and colleagues (2002) reviewed the medical charts of 363 persons over the age of 50 years hospitalized for hip fractures not caused by high-energy trauma or related to a pathologic condition. The study included 110 men and 253 women. The original intent of the study was to evaluate whether men received less treatment for osteoporosis than women; however, study results indicated that both men and women were under-treated for the disease. At the time of hospital discharge, only 4.5% of men and 27% of women received some form of treatment for osteoporosis (Kiebzak et al. 2002), although the majority of these women had been on treatment prior to hospitalization. A 1 – 5 year follow-up of 168 of the surviving subjects revealed that 27%, or 12 of 44 men were receiving osteoporosis treatment, most of which involved calcium and vitamin D supplementation. Of 124 female subjects, 71% were on treatment

regimens. During this time, only 11% of men and 27% of women reported having any type of bone density measurement, despite a history of previous fracture.

It has been suggested that although osteoporosis diagnosis in not typically an immediate concern in an acute care setting, it is a condition that can be addressed and tested in subsequent follow-up visits with a primary care physician (Kiebzak et al. 2002). The results of Kiebzak and colleagues' (2002) study suggest a lack of physician awareness of the need to identify and treat those individuals at high risk for developing osteoporosis. As the above study subjects were elderly, it becomes questionable if healthcare professionals are aggressively identifying those younger men and women who present with risk factors for primary or secondary osteoporosis. Physicians also provide less diagnostic and preventive care for African-American females over the age of 50 years when compared to their white counterparts, even when the African-American women had experienced previous fractures (Mudano et al. 2003). These findings suggest a need for increased physician awareness and the need for osteoporosis prevention to begin early in life. In addition, individuals other than elderly white women are at risk for developing this condition as they age. Osteoporosis is a disease that must be prevented in youth by attaining and maintaining peak bone mass; therefore, educational strategies for prevention are crucial for children, men, and premenopausal women.

Prevention Education

Information on the numbers of premenopausal and postmenopausal women who receive information about osteoporosis from their primary care physician is limited. One telephone survey of 505 women between the ages of 18 – 65 years found that only 44% could recall having a discussion with a healthcare provider about bone density or calcium

intake (Opinion Research Corporation International 1996). A review of family practice clinics utilized patient interviews immediately following an annual health maintenance examination to determine the level of physician education for bone density issues (Schrager et al. 2000). Four hundred forty-nine females aged 18 – 65 years were asked after an annual examination if the physician had discussed osteoporosis or calcium intake during the visit. Approximately 33% of women under the age of 40 years reported having such a discussion, whereas the proportions increased to 50% for women over age 40 years and 60% for women aged 50 – 60 years. Regression analysis indicated that women under the age of 50 years were less likely to have discussions regarding osteoporosis prevention than their older counterparts. Further analysis revealed that female providers were significantly more likely to provide bone density information than their male counterparts ($P = 0.004$). A chart review was not completed to confirm patient recalls (Schrager et al. 2000).

Additional analysis of 138 women aged 25 years and over who had previously received BMD results was conducted by Nickols-Richardson and colleagues (2002) to determine what, if any, actions these women took after receipt of test results. Approximately 62% of these women reported sharing their results with a health professional, with 80% of these respondents reporting data directly to their primary care physicians. Of those women with low BMD, only 25% were advised by their physicians to undergo additional testing to identify a secondary cause for low bone mass. Similarly, only 40% of participants with low BMD who shared the results with a health professional received advice for dietary and lifestyle changes (Nickols-Richardson et al. 2002). While the advice did include encouragement to increase calcium intake and vitamin D

supplement use, as well as to increase general physical activity, no participants received information regarding effects of dietary caffeine, salt, or alcohol intake on bone. None were encouraged to consume food sources of vitamin D or to engage in lifestyle factors to improve bone density, such as specific bone-building exercises or smoking cessation (Nickols-Richardson et al. 2002). Results from the above follow-up study suggest that healthcare professionals need to become more aware of lifestyle factors women can implement to improve BMD, and that these professionals need to develop appropriate referral services if additional testing or counseling are warranted.

While rates of osteoporosis discussion appear to increase as patients age, it is important that young females also receive prevention information, as this is the time during which bone mass can be improved and maintained. Data indicate that young women are less likely than their older counterparts to have these discussions or to implement lifestyle changes, such as exercise, after learning that they have low BMD levels (Nickols-Richardson et al. 2002, Schrager et al. 2000). The study by Schrager and colleagues (2000) did use recall information from only one visit, possibly resulting in biased results if providers had discussed osteoporosis with the woman at a previous visit. However, the results clearly highlight the need for healthcare providers to increase awareness of the benefits of osteoporosis prevention in a young, premenopausal population, particularly in minority groups who may or may not have received information on osteoporosis prevention prior to the physician visit.

Consumer Awareness

Today's consumers are faced with a multitude of information regarding health, which may or may not be accurate. The general population requires adequate knowledge

of osteoporosis risk factors and prevention strategies if they are to proactively improve their bone density status before the age of 50 years, or prior to menopause for women. Currently, the most often used sources of information for osteoporosis by women include internet sites, pamphlets, health newsletters, and books (Nickols-Richardson et al. 2002). Each of these sources represents an opportunity for involvement by healthcare professionals.

Larkey and colleagues (2003) used phone surveys to evaluate osteoporosis prevention knowledge in an ethnically diverse population of 200 females aged 25 – 55 years. The sample was comprised of 43 (21.5%) Hispanics, 11 (5.5%) African-Americans, 2 (1%) American Indians, and 20 (10%) subjects classified as "other". Respondents provided answers to questions regarding modifiable risk factors such as dietary intake, weight-bearing exercise, and smoking. They also stated if they had ever undergone bone density testing or used hormone replacement therapy. Results indicated that while 77% of women claimed to understand what osteoporosis was, only 58.5% actually provided a correct answer. Women of all ages were also unaware of the relationship between osteoporosis prevention and weight-bearing exercise. Although 73% of participants agreed that resistance training could improve bone mass, another 43% felt that "daily light activities" prevented osteoporosis, while 9% felt that walking could significantly improve bone mass. Approximately 62% of the participants who claimed to engage in physical activity also cited walking as their main form of exercise (Larkey et al. 2003).

Analysis of food frequency questionnaires revealed that study participants consumed an average of 4.3 – 5 servings of calcium rich foods daily, but that Hispanic

females were more likely to obtain calcium from beans and corn tortillas as opposed to non-Hispanics who had slightly higher milk consumption at 1.8 versus 1.3 servings daily (Larkey et al. 2003). The study was limited in that a possible bias with phone interviews and participant recalls could somewhat affect results, but the overall results provided valuable insight into osteoporosis knowledge of pre- and perimenopausal women. These women need information concerning good calcium sources that are culturally appropriate and exercises that can effectively improve or maintain bone mass.

There is a growing body of evidence that physicians and consumers are unaware of the importance of osteoporosis prevention and treatment throughout the life cycle (Kiebzak et al. 2002, Larkey et al. 2003, Mudano et al. 2003, Schrager et al. 1999), although consumers are often willing to initiate positive lifestyle changes when notified of their bone density status (Nickols-Richardson et al. 2002). Surveys designed to identify those younger adults with a high risk of developing osteoporosis later in life can assist healthcare professionals in determining which individuals need additional counseling and osteoporosis prevention education.

Osteoporosis Risk Detection

In recent years, technology has allowed clinicians to detect low BMD using a variety of methods (Johnston et al. 1991). Unfortunately, those methods that are most accurate and successful can be too cost-prohibitive to warrant universal BMD screening ("Analysis of the effectiveness…" 1998). Although there are no official rules stating who should undergo screening, many organizations and researchers have proposed guidelines and surveys designed to detect which older women are at high risk for developing osteoporosis ("Assessment of fracture risk…" 1994, Cadarette et al. 2000,

Cadarette et al. 2001, National Osteoporosis Foundation 1998, Weinstein & Ullery 2000). Surveys that have been validated in postmenopausal women use BMD measurements from dual-energy X-ray absorptiometry (DXA) as the standard to evaluate each tool's effectiveness (Cadarette et al. 2000, Cadarette et al. 2001, Lydick et al. 1998, National Osteoporosis Foundation 1998, Weinstein & Ullery 2000). A review of the current validated surveys and BMD measurement methods is presented.

Survey Tools

Several survey tools and guidelines, also known as decision rules, have been developed to facilitate the identification of those individuals who are at an increased risk for low BMD ("Assessment of fracture risk…" 1994, Cadarette et al. 2000, Cadarette et al. 2001, Lydick et al. 1998, National Osteoporosis Foundation 1998, Weinstein & Ullery 2000). Evaluations of some decision rules have found them to have poor sensitivity or to be too difficult to implement in clinical practice; however, other guidelines have higher levels of sensitivity and specificity in certain populations (Cadarette et al. 2001, Sedrine et al. 2002). The majority of currently available surveys are validated only in postmenopausal women. The National Osteoporosis Foundation's guidelines for physicians rely on clinical trial data to provide decision rules for DXA testing in postmenopausal white females (National Osteoporosis Foundation 1998). The guidelines recommend DXA testing only in those postmenopausal women over 65 years of age with risk factors who are considering treatment to increase bone mass. They also acknowledge that women under the age of 65 years with additional risk factors other than menopause could benefit from BMD testing. Risk factors include a personal or family history of bone fracture, an age over 65 years, a weight less than 57.6 kilograms (kg), and

current smoking status. The guidelines also state that due to a lack of research available for rules regarding men, premenopausal women, and non-caucasian women, these groups should follow universal prevention guidelines regarding diet and physical activity, and do not provide recommendations for DXA screening in these populations (National Osteoporosis Foundation 1998).

A survey tool for low BMD detection was developed by evaluating questionnaires completed for 1,279 postmenopausal women at 106 participating health centers (Lydick et al. 1998). Using a regression model, investigators designed the Simple Calculated Osteoporosis Risk Estimation (SCORE) tool. The decision rule risk factors included ethnicity, estrogen use, history of rheumatoid arthritis, fracture history, an age over 65 years, and a weight criterion of -1 times the weight in pounds divided by ten. The SCORE tool was then validated in a cohort of 207 postmenopausal women, resulting in a sensitivity of 91% and a specificity of 40%. This means that 91% of women with low bone mass were selected for further examination, and 40% of women with normal BMD levels were not selected for further examination. Researchers concluded that the survey was a cost-effective method to detect low BMD in post-menopausal females (Lydick et al. 1998). Subsequent attempts to verify the instrument's specificity levels indicated that the tool was not cost-effective, as it selected a large number of women with normal BMD levels for DXA testing (Cadarette et al. 1999, Von Muhlen et al. 1999). The tool was tested using a cohort of postmenopausal women and was not validated for use in men or premenopausal women.

An additional BMD decision rule was validated as a part of the Canadian MultiCentre Osteoporosis Study (CaMos) (Cadarette et al. 2000). All eligible women

aged 45 years and older gave extensive information concerning past medical histories and lifestyle information, then underwent DXA testing at the hip and lumbar spine. Two-thirds, or 926, test subjects were used to develop the survey, and the remaining one-third, or 450, subjects were tested for its validation. A T-score of -2 was used as a reference point for high osteoporosis risk. Logistic regression analysis determined which risk factors correlated significantly with low BMD, while area under the receiver operating characteristics curves (AUROC) were used to validate those items (Cadarette et al. 2000).

Researchers determined that the indicators contributing to the highest degrees of sensitivity and specificity were age, weight, and current estrogen use. The survey was titled the Osteoporosis Risk Assessment Instrument (ORAI). The final tool did select 43% of women with normal BMD values for DXA testing during the validation phase (Cadarette et al. 2000). It also did not address any recommendations for follow-up treatment with a physician if the survey result indicated a high osteoporosis risk. It was unclear if the instrument could be applied to men or premenopausal women younger than 45 years of age.

Investigators have made attempts to validate survey tools in Asian women (Koh et al. 2001). The Osteoporosis Self-Assessment Screening Tool (OST) was developed based on univariate model analysis of 12 potential risk factors for osteoporosis in postmenopausal women, including age, weight, height, race, fracture history, age at menopause, medication use, calcium intake, rheumatoid arthritis, smoking history, physical activity, and sunlight exposure. A total of 860 Asian women provided risk factor information and DXA measurements at the hip. Based on DXA results and multiple variable models researchers concluded that using only age and weight in the

survey produced a decision rule with 91% sensitivity and 45% specificity (Koh et al. 2001). The ORAI and SCORE were also evaluated in the women with sensitivity and specificity scores of 84% and 52% for ORAI and 90% and 33% for SCORE.

The OST performed equally well with the ORAI and SCORE in detecting post-menopausal Asian women with low BMD. Adler and colleagues (2003) also validated the survey tool in a cohort of 181 male veterans with an average age of 64.3 years at a sensitivity level of 93% and specificity level of 66%. While the OST was effective as a screening tool for postmenopausal women and elderly men, it has not been validated for use in premenopausal women and younger men (Adler et al. 2003, Koh et al. 2001). Its applicability in these populations is questionable as those with a younger age would have a higher OST index and not be recommended for bone density intervention, regardless of actual weight or dietary intake.

Researchers participating in the CaMos studies evaluated four decision rules and the National Osteoporosis Foundation (NOF) guidelines for referring women for DXA testing, including two of the above mentioned methods (Cadarette et al. 2001). To evaluate the four methods – SCORE, ORAI, Age, Body Size, No Estrogen (ABONE), and body weight less than 70 kg (weight criterion) – researchers evaluated 2,365 women over 45 years of age without bone disease. The women underwent DXA testing at the femoral neck, after which actual results were compared with the survey recommendations and NOF guidelines. A T-score of -2 was used for treatment threshold, and AUROC curves were used to evaluate the effectiveness of each decision rule (Cadarette et al. 2001).

Study authors revealed that the ORAI, SCORE, and NOF guidelines all selected over 94% of women with a T-score less than -2 for testing and 96% of subjects with clinical osteoporosis, or a T-score less than -2.5. The ORAI selected 56% of women with normal BMD levels for DXA testing, whereas the SCORE and NOF rules selected 69% and 74%, respectively. Researchers determine that the ORAI decision rule was the most efficient and effective tool for detecting low BMD in elderly women, while SCORE and NOF guidelines were also effective but not as efficient (Cadarette et al. 2001). A comparison of the various survey tools is presented in Table 2 (Adler et al. 2003, Cadarette et al. 2001, Koh et al. 2001).

The study authors did acknowledge that there was a possible volunteer bias, with those adults most concerned with bone health agreeing to participate. There was also significant over – sampling of the older population, limiting the study's application to younger or male populations and possibly giving those surveys that placed greater emphasis on age an advantage. Further study was warranted to evaluate the practicality of using each decision rule in clinical practice (Cadarette et al. 2001), and to determine if any of the tools could be used effectively in a younger population. In order to validate the above surveys in such a cohort, it would be necessary to evaluate DXA measurements of BMD and bone mineral content (BMC) to determine if the specificity and sensitivity r ates among the young population were comparable to those of elderly women.

Bone Mineral Density Testing

A variety of methods currently exists to measure BMD, including quantitative computed tomography, ultrasound of the calcaneous and knee areas, and DXA

Table 2

Comparison of Survey Tools Used to Detect Low BMD in Women and Men

Test	Sensitivity	Specificity	AUROC
NOF	96.2%	17.8%	0.70
SCORE	99.6%	17.9%	0.80
ORAI	97.5%	27.8%	0.79
OST (women)	91%	45%	N/A*
OST (men)	93%	66%	0.836

N/A = not applicable: information not provided

(Johnston et al. 1991). These methods allow investigators to monitor bone mineral changes in the individual over time. They are also suitable for population screening at-large. Multiple bone mineral measurements allow health professionals to monitor treatment effectiveness in individuals after initial identification of low bone mass, although certain types of measures are more precise than others.

While ultrasound measurements are beneficial for large-scale screening within the population, DXA is considered the preferred method of bone density measurement as it provides greater accuracy than the aforementioned methods. The DXA machine has the ability to measure both bone mineral content (BMC) and BMD while also providing an analysis of soft tissue composition (Madsen et al. 1997). Two separate wavelengths of photons emanate from the machine, which provides it with the ability to distinguish between tissue types. Such precision in measuring also enables the individual to receive site-specific bone measurements of the spine, hip, and wrist (Cummings & Black 1995, Johnston et al. 1991, Rizzoli et al. 1995, Shagam 2003). Portable DXA machines, or pDXA, are available to measure peripheral skeletal sites (Shagam 2003). Due to the status of DXA as the "gold standard" for BMD testing, researchers have relied on it in published literature to validate survey tools designed to distinguish between those individuals who warrant BMD testing versus those who have adequate bone mass ("Assessment of fracture risk…" 1994, Cadarette et al. 2000, Cadarette et al. 2001, Lydick et al. 1998, National Osteoporosis Foundation 1998, Weinstein & Ullery 2000). While this method does not provide information concerning the quality of bone, it is the best clinical indicator of overall bone mass, and would be the preferred method in clinical

practice to establish a diagnosis of low bone density if a survey tool indicated the presence of osteopenia or osteoporosis.

Summary

Osteoporosis is a debilitating bone disease that can be caused by a multitude of lifestyle and metabolic factors. The most effective treatment for osteoporosis remains prevention in adolescents and young adults. Current medications that treat the disease can minimize bone loss, but do not adequately assist with building bone mass. It is therefore imperative that young adults be aware of their risk factors for osteoporosis and which prevention strategies are most effective for them. Research concerning the prevalence of low BMD in young adults is limited. Currently, healthcare professionals do not have access to validated survey tools that could identify young adults in need of osteoporosis prevention education. Moreover, evidence suggests that physicians do not adequately treat elderly patients with a diagnosis of osteoporosis or osteopenia. When they do discuss the disease with their patients, physicians are more likely to provide prevention strategies to elderly white women compared to men and premenopausal women of various ethnicities. Survey tools to identify postmenopausal women at high risk for low BMD are available but have not been validated in younger cohorts of men and women. To accomplish such goals, the purpose of this research was to: (1) determine whether currently existing survey tools designed to detect osteoporosis risk in postmenopausal females were also applicable to a younger adult population, and to (2) determine if those adults with risk factors for osteoporosis have been informed of having a high-risk status by any healthcare professional.

Chapter 3

Materials and Methods

A cross-sectional investigation was designed to evaluate current practices regarding low bone density identification in young adults. Participants completed three survey tools which the investigator compared to the subjects' DXA test results to determine the effectiveness of each survey designed to identify low bone mass.

Study Participants

Forty-two adult men and 41 adult women, aged 20 to 40 years, were recruited from Virginia Polytechnic Institute and State University (Virginia Tech, Blacksburg, VA, U.S.A.) and the surrounding community using flyers, direct contact, and electronic mailings. The research project was approved by the Institutional Review Board for Research Involving Human Subjects at Virginia Tech. Prior to study participation, each participant read and signed an informed consent form. Participants were allowed the opportunity to ask the investigator any questions regarding the study protocol prior to providing informed, written consent.

A general health questionnaire designed by departmental faculty and the investigator was used to screen potential study participants. Individuals were excluded if they: (1) were under 20 or over 40 years of age, (2) were postmenopausal or perimenopausal women, (3) had physician-diagnosed metabolic bone disease, or (4) had used any prescription medications during the past year specifically for the purpose of improving bone density. Participants with secondary risk factors for osteoporosis, including hyperthyroidism and metabolic syndrome, were included in all final data analyses. The study was designed to evaluate healthcare practitioners' effectiveness

when identifying young adults at risk for bone disease; therefore, inclusion of these data allowed the investigator to determine if the health community was actively educating such persons about their risk levels. In addition, one survey tool allocated points to participants with rheumatoid arthritis; consequently, any individuals with that diagnosis were included in the final analyses. It was decided that a minimum of 40 participants was needed to achieve 95% confidence at $p = 0.05$ for area under the receiver operating characteristic (AUROC) curves; therefore, a minimum of 40 men and 40 women was recruited for analyses.

Procedures

The complete study protocol was carried out in the Bone Metabolism, Osteoporosis, and Nutrition Evaluation Laboratory at Virginia Tech University. During a one-hour testing session, the investigator collected personal, anthropometric and body composition data. Participants also completed three survey tools previously designed and validated to detect low bone density in postmenopausal women. Data were collected between April 13, 2004, and May 14, 2004. Eighty-three participants completed all procedures.

Personal Data

Each participant provided a date of birth, past medical history, and physical activity habit profile. This information was used to confirm study eligibility within the age and medical constraints. Participants also answered questions used to determine if a healthcare professional had ever discussed osteoporosis or risk factors for having low bone density with participants. Histories regarding individual medical risk factors for low bone density and whether a healthcare professional had notified the participant of his or

her risk for osteoporosis were used to analyze current physician practices regarding osteoporosis education and prevention.

Anthropometric Data

Body weight was measured using a calibrated electronic scale (Scaletronix, Wheaton, IL, U.S.A.). Body height was measured with a wall-mounted stadiometer (ACCUSTAT, Ross Laboratories, Columbus, OH, U.S.A.). Each participant was shoeless and lightly clothed for standing height and weight measurements. Weights and heights were documented to the nearest 0.1 kg and 0.1 cm, respectively, and were used to calculate body mass index (BMI; kg/m^2) for each participant. Data were converted to pounds and inches for bone density patient profiles.

Survey Instruments

Participants completed three questionnaires validated for use in postmenopausal women, including the: (1) National Osteoporosis Foundation (NOF) Survey, (2) Osteoporosis Risk Assessment Instrument (ORAI), and (3) Simple Calculated Osteoporosis Risk Estimation (SCORE) Survey. Scoring methods used were consistent with those established by the ORAI and SCORE developers; scoring methods for the NOF Survey were evaluated by the investigator (Cadarette et al. 2000, Lydick et al. 1998, National Osteoporosis Foundation 1998).

NOF Survey: This survey tool was designed to identify participants at risk for low bone mass as those persons with: (1) a small frame size, (2) a weight less than 57.6 kg or approximately 127 lbs., (3) a personal or family history of bone fracture, (4) menopausal status, (5) ethnicity, (6) use of bone-depleting medications, (7) a history of excess alcohol use, (8) consistent physical inactivity, (9) a history of cigarette smoking,

or (10) low dietary calcium intake. The NOF did not established a scoring method for this survey tool; however, past research supported the use of allowing one point for each risk factor. General guidelines established by the NOF recommend further testing of women over age 65 years at a score of one or above (National Osteoporosis Foundation, 1998), and high risk status was evaluated at a score of one or greater. Additionally, the survey tool studied indicated that the more risk factors participants selected, the higher their risk for low BMD became; therefore, high risk status was also evaluated by the investigator at a score greater than or equal to three.

ORAI: This instrument was designed to base osteoporosis risk levels on: (1) the age categories of 55 to 64 years, 65 to 74 years, and 75 years or older, (2) a weight range of 60 to 70 kg (132 to 154 lbs) or less than 60 kg, and (3) use of estrogen – containing medications. A score of nine or greater indicated that the participant was at risk for low bone mass (Cadarette et al. 2000).

SCORE Survey: The SCORE instrument was created to identify osteoporosis risk levels based on: (1) race, (2) bone fracture history, (3) an age over 65 years, (4) weight, (5) estrogen use, and (6) diagnosis of rheumatoid arthritis. Participants with a score of at least six were considered at high risk for low BMD levels (Lydick et al. 1998).

Bone Mineral Density Measurements

Prior to BMD analyses, all women submitted a urine sample for pregnancy testing (QuPID, Stanbio Laboratory, Boerne, TX). Forty-one women received a negative test result and completed BMD testing.

Dual-energy X-ray absorptiometry (QDR 4500A, Hologic, Inc., Bedford, MA) was used to measure total body (TB), lumbar spine (LS, L2-L4), total forearm (TF, radius

and ulna, comprised of the proximal, mid, and distal one-third forearm), and total proximal femur (TPF, including the femoral neck, trochanter, and Ward's triangle) BMD (g/cm^2). Version 8.25a of the Whole Body Fan Beam software was used for analyses. All scans were conducted and analyzed by one Licensed Radiologic Technologist-Limited.

Hypothesis

All test results were used to (1) determine whether currently existing survey tools designed to detect osteoporosis risk in postmenopausal females were also applicable to a younger adult population, and to (2) determine if those adults with risk factors for osteoporosis were informed of having a high-risk status by any healthcare professional. If physicians did aggressively identify young adults with low bone mass, additional survey tools would not be warranted. Two hypotheses were tested:

1) Healthcare workers do not provide osteoporosis information to at least 50% of patients aged 20-40 years.
2) There will be no significant difference among decision rules in detecting low bone density levels in men and women ages 20-40 years.

Statistical Analysis

All statistical analyses were completed with the Statistical Package for the Social Sciences (SPSS) statistical software (SPSS Inc., Chicago, IL., version 12.0, 2003). Mean and standard deviations (M ± SD) were computed for each variable under analysis. Outcome measures for the survey tools were determined at three degrees of low BMD: (1) a T-score ≤ -1.0 (moderate osteopenia), (2) a T-score ≤ -2.0 (severe osteopenia) and (3) a T-score ≤ -2.5 (osteoporosis). Chi-square analyses were completed to identify any

differences in physician education between low and normal BMD groups, gender, and age levels. Unpaired, two-tailed *t*–tests were used to compare mean BMD values between men and women. Sensitivity and specificity were computed to analyze the accuracy of each survey tool. Sensitivity was used to determine each survey's ability to correctly identify participants who were at risk for low BMD levels. Specificity levels revealed each survey's ability to rule out those participants who were not at risk for low BMD levels. The area under the receiver operating characteristic (AUROC) curve was applied to compare the overall effectiveness of the three survey instruments. A significance level of $p = 0.05$ with 95% confidence interval (CI) was determined for all calculations.

Chapter 4

Results

Eighty-three participants completed the health questionnaire; 41 women and 42 men were included in final analyses.

Anthropometric Data

Characteristics of the study population are listed in Table 1. The mean age (± SD) of participants was 27.4 ± 5.2 years. The majority of participants classified themselves as Caucasian (79.5%; n=66), with additional reported ethnicities of Latino/Hispanic (7.2%; n=6), African descent (4.8%; n=4), Indian Asian (4.8%; n=4) and Asian (3.6%; n=3). Female participants were classified as Caucasian (80.5%; n=33), Latino/Hispanic (4.9%; n=2), African descent (4.9%; n=2), Indian Asian (4.9%; n=2) and Asian (4.9%; n=2). Male participants were classified as Caucasian (78.6%; n=33), Latino/Hispanic (9.5%; n=4), African descent (4.8%; n=2), Indian Asian (4.8%; n=2) and Asian (2.4%; n=1).

On average, participants weighed 72.4 ± 15.3 kg (range, 43.7 – 125.8 kg), with a height of 171.3 ± 8.5 cm (range, 147.3 – 193.0) and BMI of 24.1 ± 3.7 (range, 18.5 – 36.0 kg). Five (12.2%) female participants were classified as underweight (BMI ≤ 19.0). Thirty (73.2%) women and 22 (52.4%) men were of normal weight (BMI = 19.1-25.0), 5 (12.2%) women and 14 (33.3%) men were overweight (BMI = 25.1-29.9), and 1 (2.4%) woman and 6 (14.3%) men were obese (BMI ≥ 30).

General health characteristics of the study population are listed in Table 2. Among women, 51.2% (n=21) reported using an estrogen – containing oral contraceptive. Twenty-three percent (n=19) reported a family history of osteoporosis, with diagnosed

TABLE 1. Characteristics of Study Population.

Variable	Mean ± SD	Range
All subjects: (n=83)		
Age (y)	27.4 ± 5.2	20 – 40
Height (cm)	171.3 ± 8.5	147.3 – 193.0
Weight (kg)	72.4 ± 15.3	43.7 – 125.8
Body Mass Index (kg/m2)	24.1 ± 3.7	18.5 – 36.0
Body Fat (%)	23.0 ± 7.8	8.0 – 40.7
Women: (n=41)		
Age (y)	26.9 ± 5.2	20 – 39
Height (cm)	165.9 ± 6.7	147.3 – 177.8
Weight (kg)	62.4 ± 10.8	43.7 – 92.1
Body Mass Index (kg/m2)	22.3 ± 3.0	18.5 – 32 .0
Body Fat (%)	26.7 ± 6.5	15.2 – 40.7
Men: (n=42)		
Age (y)	27.9 ± 5.2	20 – 40
Height (cm)	176.5 ± 6.5	165.1 – 193.0
Weight (kg)	82.1 ± 12.6	63.9 – 125.8
Body Mass Index (kg/m2)	25.8 ± 3.6	21.0 – 36.0
Body Fat (%)	19.5 ± 7.4	8.0 – 38.3

family members including a mother (9.8%; n=4), grandmother (39.0%; n=16), great – grandmother (4.9%; n=2), or grandfather (2.4%; n=1). Additionally, 14.6% (n=6) of women reported diagnoses that contribute to secondary osteoporosis, including anorexia (7.3%; n=3), celiac disease (2.4%; n=1), insulin–dependent diabetes (2.4%; n=1), and diabetes insipidus (2.4%, n=1). The one participant diagnosed with diabetes insipidus reported use of corticosteroids. A review of common osteoporotic fracture sites revealed that broken wrists were reported by 4.9% (n=2) of the women. Of these women, 1 of the 3 diagnosed with anorexia had been informed of osteoporosis risk, as had 1 woman diagnosed with diabetes insipidus and 2 women with a family history of osteoporosis.

Nineteen percent (n=8) of men reported a family history of osteoporosis, with diagnosed family members including a mother (9.5%; n=4), grandmother (11.9%; n=5), or father (2.4%; n=1). A medical diagnoses of metabolic syndrome, which contributes to secondary osteoporosis, was reported by 2.4% (n=1) of men. One (2.4%) man reported corticosteroid use. Moreover, 9.5% (n=4) of men reported a history of bone fracture at the forearm. Of these men, 2 reported receipt of bone health information: 1 participant with a history of corticosteroid use, and 1 with a history of forearm fracture.

Healthcare Provider Education

Among participants, 19.5% (n=8) of women and 7% (n=3) of men reported at least one previous discussion with a healthcare provider about osteoporosis risk and prevention. Table 3 identifies those healthcare professionals who provided participants with such information. Women participants were more likely to identify an obstetrician/gynecologist (25%; n=2) as the healthcare professional who provided them with information on bone health. Women also discussed osteoporosis risk with a

TABLE 2. General Health Characteristics of Participants*

	Women	Men
Oral Contraceptive Use (n=21)	21 (51.2)	N/A†
Family History of Osteoporosis: (n=27)		
Mother	4 (14.8)	4 (14.8)
Grandmother	16 (59.3)	5 (18.5)
Great – Grandmother	2 (7.4)	0 (0.0)
Father	0 (0.0)	1 (3.7)
Grandfather	1 (3.7)	0 (0.0)
Medical Diagnoses: (n=7)		
Anorexia Nervosa	3 (42.9)	0 (0.0)
Celiac Disease	1 (14.3)	0 (0.0)
Diabetes Insipidus	1 (14.3)	0 (0.0)
Insulin–Dependent Diabetes	1 (14.3)	0 (0.0)
Metabolic Syndrome	0 (0.0)	1 (14.3)
Corticosteroid Use (n=2)	1 (50)	1 (50)
Common Osteoporotic Fracture Sites: (n=6)		
Spine	0 (0.0)	0 (0.0)
Hip	0 (0.0)	0 (0.0)
Wrist	2 (33.3)	4 (67.7)

*Expressed as number (percent) of participants. Values are not equal to 100% as multiple responses were possible.
† N/A = not applicable

TABLE 3. Healthcare Providers Who Discussed Osteoporosis Risk With Participants (n=11)

Healthcare Provider	Number (Percent) of Participants
Nurse Practitioner	3 (28)
Primary Care Physician	2 (18)
Obstetrician/Gynecologist	2 (18)
Orthopedic Surgeon	1 (9)
Chiropractor	1 (9)
Radiologic Technologist – Limited	1 (9)
University Researcher	1 (9)

chiropractor (12.5%; n=1), nurse practitioner (25%; n=2), primary care physician (12.5%; n=1), orthopedic surgeon (12.5%; n=1), and a university researcher (12.5%; n=1). One of the 2 women who received information from a nurse practitioner visited the health professional at an employee health fair. Men (7%; n=3) reported that they received information regarding osteoporosis from a primary care physician (33.3%; n=1), a nurse practitioner (33.3%; n=1) and a radiologic technologist–limited (33.3%; n=1).

Chi-Square Analysis

Participants were grouped into BMD T-score categories of a T-score ≤ -2.5 (osteoporosis), a T-score ≤ -2.0 (severe osteopenia), a T-score ≤ -1.0 (moderate osteopenia) and a T-score > -1.0 (normal BMD) to determine if healthcare professionals were more likely to discuss osteoporosis risk with those participants who had lower bone density. Healthcare providers were not significantly more likely to discuss osteoporosis risk with participants who had low T-scores. Furthermore, no significant difference was detected in the rates of osteoporosis discussion between health professionals and men (7%; n=3) and women (19.5%; n=8). Women over age 30 (23.4%; n=10) were no more likely than their younger counterparts (75.6%; n=31)) to discuss osteoporosis with a healthcare provider; moreover, men over age 30 (35.7%; n=15) did not receive more information regarding osteoporosis risk than did men under age 30 (64.3%; n=27).

Evaluation of Decision Rules

Based on DXA scan results, 32.0% (n=13) of women and 42.9% (n=18) of men had at least one body site with a T-score ≤ -1.0. Dual–energy X–ray absorptiometry scans also revealed that of women participants, 4.9% (n=2) had at least one body site with a T-score ≤ -2.0, and 2.4% (n=1) had at least one body site with a T-score ≤ -2.5,

TABLE 4. Number (Percent) of Participants with Osteopenia, Severe Osteopenia, and Osteoporosis

	Women	Men	Total
T-score ≤ -1.0 (Osteopenia)	13 (32.0)	18 (42.9)	31 (37.3)
T-score ≤ -2.0 (Severe Osteopenia)	2 (4.9)	5 (11.9	7 (8.4)
T-score ≤ -2.5 (Osteoporosis)	1 (2.4)	3 (7.1)	4 (4.8)

compared to 11.9% (n=5) of men with T-scores ≤ -2.0, and 7.1% (n=3) men with T-scores ≤ -2.5. Results are reported in Table 4.

Average T-scores for the lumbar spine, proximal femur and forearm of all study participants are reviewed in Table 5. Average total body T-scores are provided for women only, as normative T-score values are currently not available for men. There was no significant difference between T-scores of the proximal femur or lumbar spine between men and women. Independent *t*-tests revealed women had a significantly higher T-score of 0.381 ± 0.766 at the forearm compared to an average T-score of -0.035 ± 0.996 for men ($p = 0.036$).

NOF Survey

One hundred percent (n=41) of women and 95.2% (n=40) of men received positive results when the NOF was scored at a risk threshold of 1. Of these participants, 32.0% (n=13) of women and 40.5% (n=17) of men had at least one body site with a T-score ≤ -1.0. At a risk threshold of 3, 39.0% (n=16) of women and 23.8% (n=10) of men were identified for osteoporosis risk, of which 31.3% (n=5) of women and 33.3% (n=3) had at least one body site with a T-score ≤ -1.0. The average NOF test score (Table 7) was 2.2 ± 1.1 for women, 1.7 ± 0.9 for men, and 2.0 ± 1.0 for the entire sample. The frequency distribution of NOF test scores is listed in Table 6.

ORAI survey

Forty-four percent (n=18) of women and 0.0% (n=0) of men received positive results when the ORAI was scored at a risk threshold of 9. Of those women with scores greater than 9, 31.3% (n=5) had at least one body site with a T-score ≤ -1.0. The average

TABLE 5. Average Bone Mineral Density (BMD) T–scores of Study Participants (n=83)*

	Total (SD)	Women (SD)	Men (SD)	P-value †
Total Body	N/A	0.48 ± 0.88	N/A	N/A
Lumbar Spine	-0.38 ± 1.15	-0.39 ± 0.96	-0.37 ± 1.31	NS
Proximal Femur	0.12 ± 0.97	0.15 ± 1.09	0.09 ± 0.85	NS
Total Forearm	0.17 ± 0.91	0.38 ± 0.77	-0.04 ± 0.10	0.036

*SD = standard deviation
*N/A = not applicable
*NS = not significant
†P-values from *t*-test comparisons; $p < 0.05$

TABLE 6. Survey Score Distribution (n=83)*

	Women	**Men**	**Total**
NOF Survey:			
0	0	2	2
1	15	18	33
2	10	12	22
3	11	9	20
4	4	1	5
5	1	0	1
ORAI Survey:			
0	2	36	38
1	0	0	0
2	4	0	4
3	10	6	16
4	0	0	0
5	7	0	7
6	0	0	0
7	0	0	0
8	0	0	0
9	9	0	9
10	0	0	0
11	9	0	9

*Results by # participants for National Osteoporosis Foundation (NOF) and Osteoporosis Risk Assessment Instrument (ORAI) surveys. Dashed line = risk threshold.

ORAI test score (Table 7) was 6.2 ± 3.7 for women, 0.4 ± 1.0 for men, and 3.2 ± 3.9 for the entire sample. The frequency distribution of ORAI test scores is listed in Table 6.

SCORE survey

The SCORE survey did not select any participants as having a high risk for low BMD at a risk threshold of 6. The average SCORE test result (Table 7) was -1.9 ± 2.8 for women, -5.5 ± 4.0 for men, and -3.7 ± 3.9 for the entire sample.

Comparisons

Average scores for the NOF, ORAI, and SCORE surveys are listed in Table 7. The sensitivity, specificity and AUROC curve were computed for each survey with a 95% CI at cutoff point T-scores of ≤ -1.0, ≤ -2.0 and ≤ -2.5. The results are summarized in Table 8. Surveys were also evaluated separately for men (Table 9) and women (Table 10). Results were analyzed for the NOF survey with a trigger score of 1 (NOF 1), the NOF survey with a trigger score of 3 (NOF 3), the ORAI and SCORE.

The SCORE survey did not identify any study participants as having a high risk for low BMD; therefore, all AUROC curves for SCORE were 0.500 with a sensitivity of 0.00% and a specificity of 100%. NOF 1 had sensitivity rates of 96.8% at a T-score ≤ -1.0 and 100% at a T-score ≤ -2.5, but corresponding specificity rates were only 19% and 2.5%, respectively. This resulted in AUROC curves of only 0.513 for both cutoff points. ORAI sensitivity rates did not exceed 29% for any of the three groups, although specificity rates ranged from 76.9% - 80.3%. The AUROC curves for ORAI ranged from 0.501 - 0.544. NOF 3 had an AUROC curve of 0.598 at a T-score of ≤ -2.5, with a sensitivity of 50% and specificity of 68.4%. No other survey tools exceeded this AUROC curve level at any other cutoff point. The NOF 3 selected only 29% of total

TABLE 7. Average test scores for the NOF, ORAI, and SCORE surveys.

Variable	Mean ± SD	Range	Risk Threshold
All subjects: (n=83)			
NOF▪	2.0 ± 1.0	0 – 5	1, 3
ORAI†	3.2 ± 3.9	0 – 11	N/A*
SCORE°	-3.7 ± 3.9	-13.9 – 5.0	N/A
Women: (n=41)			
NOF	2.2 ± 1.1	1 – 5	1, 3
ORAI	6.2 ± 3.7	0 – 11	9
SCORE	-1.9 ± 2.8	-9.3 – 4.6	6
Men: (n=42)			
NOF	1.7 ± 0.9	0 – 4	1, 3
ORAI	0.4 ± 1.0	0 – 3	N/A
SCORE	-5.5 ± 4.0	-13.9 – 5.0	N/A

*N/A = not applicable; risk threshold not established for men
▪National Osteoporosis Foundation Survey
†Osteoporosis Risk Assessment Instrument
°Simple Calculated Osteoporosis Risk Estimation

TABLE 8. Sensitivity, Specificity, and Area Under the Receiver Operating Characteristic (AUROC) Curve for Decision Rules to Detect Low BMD in Adults Ages 20-40 Years at 3 T – Score Levels (n = 83)*

	Sensitivity	Specificity	AUROC†
BMD T score < -1.0 SD			
NOF (score 1)	0.968	0.190	.513
NOF (score 3)	0.290	0.654	.520
ORAI	0.161	0.769	.501
SCORE	0.000	1.000	.500
BMD T score < -2.0 SD			
NOF (score 1)	0.857	0.013	.508
NOF (score 3)	0.429	0.684	.563
ORAI	0.286	0.803	.544
SCORE	0.000	1.000	.500
BMD T score < -2.5 SD			
NOF (score 1)	1.000	0.025	.513
NOF (score 3)	0.500	0.684	.598
ORAI	0.250	0.797	.524
SCORE	0.000	1.000	.500

* p = < 0.05; 95% Confidence Interval

†Area Under the Receiver Operating Characteristic Curve

participants with a T-score ≤ -1.0 as having low BMD levels, with an AUROC curve of 0.520. At a T-score ≤ -2.0, NOF 3 selected only 42.9% of the population for testing but exhibited a sensitivity rate of 68.4%, resulting in an AUROC curve of 0.563. The investigator determined that differences in survey results between men and women were possible; therefore, a separate analysis of sensitivity, specificity and AUROC curves was conducted for each gender.

Decision rules for women

No survey tools exceeded an AUROC curve of 0.525 at a T-score ≤ -1.0 (Table 9). NOF 1 had a sensitivity of 100% but a specificity of 0.0% at each T-score level, resulting from its inability to rule out any women from testing at this score level; therefore, the AUROC curve for this tool did not exceed 0.500 at any T-score level for women. NOF 3 had sensitivity and specificity rates of 46.2% and 60.7% at a T-score ≤ -1.0, with an AUROC curve of only 0.525. The ORAI only selected 38.5% of women for testing, and combined with a specificity of 57.1% produced an AUROC curve of 0.511. However, both the NOF 3 and ORAI were able to detect 100% of women with T-scores ≤ -2.0 and ≤ -2.5, with specificity rates of 61.5% and 60%, respectively. This resulted in AUROC curves for both surveys of 0.821 and 0.813 at the more severe T-score levels. The SCORE did not detect any women at risk for low BMD, resulting in an AUROC curve of 0.500 with a sensitivity of 0.00% and specificity of 100%.

Decision rules for men

Neither the ORAI nor SCORE surveys detected any men at risk for low BMD at any of the 3 T-scores (Table 10). Both of these tests had AUROC curves of 0.500 in the

TABLE 9. Sensitivity, Specificity, and Area Under the Receiver Operating Characteristic (AUROC) Curve for Decision Rules to Detect Low BMD in Women at 3 T – Score Levels (n = 41)*

	Sensitivity	Specificity	AUROC†
BMD T score < -1.0 SD			
NOF (score 1)	1.000	0.000	0.500
NOF (score 3)	0.462	0.607	0.525
ORAI	0.385	0.571	0.511
SCORE	0.000	1.000	0.500
BMD T score < -2.0 SD			
NOF (score 1)	1.000	0.000	0.500
NOF (score 3)	1.000	0.615	0.821
ORAI	1.000	0.615	0.821
SCORE	0.000	1.000	0.500
BMD T score < -2.5 SD			
NOF (score 1)	1.000	0.000	0.500
NOF (score 3)	1.000	0.600	0.813
ORAI	1.000	0.600	0.813
SCORE	0.000	1.000	0.500

* p = < 0.05; 95% Confidence Interval

†Area Under the Receiver Operating Characteristic Curve

cohort of men. NOF 1 had sensitivity levels of 94.4% at T-scores ≤ -1.0, 80% at T-scores ≤ -2.0, and 100% at T-scores ≤ -2.5; however, reported specificity was only 4.2%, 2.7%, and 5.1%, respectively. AUROC curves for NOF 1 did not exceed 0.526 at any cutoff point. NOF 3 sensitivity was only 16.7% - 33.3% for the three test levels, whereas specificity was 70.8% - 76.9%; moreover, NOF 3 had an AUROC curve of 0.551 for a T-score ≤ -2.5. No other AUROC curve for NOF 3 exceeded 0.551. Only the NOF 1 selected over 50% of men with low BMD levels for testing; however this test was unable to rule out over 90% of men with normal BMD levels.

TABLE 10. Sensitivity, Specificity, and Area Under the Receiver Operating Characteristic (AUROC) Curve for Decision Rules to Detect Low BMD in Men at 3 T – Score Levels (n = 42)*

	Sensitivity	Specificity	AUROC†
BMD T score < -1.0 SD			
NOF (score 1)	0.944	0.042	.516
NOF (score 3)	0.167	0.708	.509
ORAI	0.000	1.000	.500
SCORE	0.000	1.000	.500
BMD T score < -2.0 SD			
NOF (score 1)	0.800	0.027	.502
NOF (score 3)	0.200	0.757	.511
ORAI	0.000	1.000	.500
SCORE	0.000	1.000	.500
BMD T score < -2.5 SD			
NOF (score 1)	1.000	0.051	.526
NOF (score 3)	0.333	0.769	.551
ORAI	0.000	1.000	.500
SCORE	0.000	1.000	.500

* p = < 0.05; 95% Confidence Interval

†Area Under the Receiver Operating Characteristic Curve

Chapter 5

Discussion

The current study was undertaken to review healthcare professional practices regarding young adults and osteoporosis education. At this time, prevention remains the best treatment for low bone density. If adequate bone density is not achieved early in life, current rates of osteoporosis and bone fractures, along with their associated costs to society, will continue to rise (Ray et al. 1997). Few studies have investigated osteoporosis discussions between health professionals and consumers under age 40 (Nickols-Richardson et al. 2002, Schrager et al. 2000), while no studies have evaluated any of the current osteoporosis survey tools for their appropriateness in a young adult population. This research provides data related to both of these issues. Healthcare professionals did not discuss osteoporosis prevention with at least 50% of the study population; the actual rate of discussion was 13.3% (n=11). At a T – score ≤ -1.0, there was no significant difference among decision rules in detecting low bone density levels in men and women aged 20-40 years. There was a significant difference between genders in survey effectiveness for the NOF (score 3) and ORAI at a T – score ≤ -2.0 and a T – score ≤ -2.5.

Results of this study must be viewed with its limitations. Participation in the study was voluntary; therefore, it is possible that volunteers had an interest in health practices or were already concerned regarding their bone health. The majority of subjects were also Caucasian, limiting this study's applicability to the general population. Participants' answers regarding bone health discussions were not validated with medical records or health professional follow-up, which could allow for subject bias. However, it

would be expected that an effective educational session would be remembered by young persons. In addition, the sample size (n=83) used to test each decision rule was smaller than those typically used to validate such surveys in older women and men (Cadarette et al. 2000, Cadarette et al. 2001, National Osteoporosis Foundation 1998, Weinstein & Ullery 2000); however, as the results clearly indicate that these decisions rules are not effective in this smaller cohort, one would expect similar findings with a larger number of participants.

Despite such limitations, several key findings were noted. Among men and women ages 20-40 years, osteoporosis risk is not frequently discussed with healthcare professionals. Healthcare professionals discussed bone health with only 13% of the study population. Women were statistically no more likely than men to receive such information, although a greater percentage (19.5% versus 7%, respectively) of women did report having bone density discussions. Research conducted by Kiebzak and colleagues (2002) indicates that men and women aged 50 years or older do not receive recommendations regarding osteoporosis risk or treatment, suggesting that, regardless of age, both genders receive inadequate osteoporosis education. Additionally, prior research confirms that women between the ages of 25 – 50 years receive less osteoporosis prevention education than their older counterparts, although this group could significantly benefit from such discussions (Nickols-Richardson et al. 2002, Schrager et al. 2000). Men and women over 30 years were no more likely to receive information regarding bone health than their younger counterparts. Previous studies found that women aged over 40 years do receive more osteoporosis education than their younger counterparts (Schrager et al. 2000); however, no studies have evaluated differences in education

between men and women aged over or under 30 years. Moreover, based on participants' T-scores, those persons currently having low BMD levels were just as likely to receive information on osteoporosis prevention than their counterparts with normal T-scores. This data suggests that healthcare professionals may not adequately discuss osteoporosis risk or prevention with adults under age 40. Furthermore, the fact that actual T-scores were not associated with an increased rate of bone health discussion suggests that health professionals do not adequately assess risk factors of young adults in this area, possibly due to the limited time allowed for each patient visit in the current healthcare system. A simple survey tool that screens patients at each visit could be very useful to identify and target those individuals with the highest risk for low BMD levels.

It is interesting to note that women reported receiving bone health information most frequently from obstetricians/gynecologists, while men had discussions concerning bone health most often with primary care physicians and nurse practitioners. Prior studies have identified primary care physicians as the main health professionals that consumers question regarding bone health information (Nickols-Richardson et al. 2002, Schrager et al. 1999, Schrager et al. 2000). This underscores the importance of including osteoporosis teaching tools in medical education for a variety of medical students and professional practitioners. It would also be important to include a nutritional component in both the medical school curriculum and continuing medical education for professionals to provide doctors and nurse practitioners with information regarding proper nutrition for bone growth and maintenance. Gynecologists, in particular, are in a unique position to discuss bone health with young women as they typically see these patients yearly. Dietitians are in a key position to promote nutrition in the school curriculum and to

provide this information as medical student educators. In addition, as more dietitians become involved in public health and nutritional counseling, they have many opportunities to emphasize osteoporosis prevention with medical nutrition therapy in multiple settings, including university health fairs, worksite wellness programs and private practice.

The NOF, ORAI and SCORE were not effective screening tools for detecting low bone density in adults aged 20-40 years. Sensitivity and specificity are two common measurements for diagnostic tests (Biggerstaff, 2000). A test with a 100% sensitivity rate would identify 100% of participants who do have the disease, while a test with 100% specificity would rule out 100% of participants who do not have the disease. A test with an AUROC curve less than 0.60 is considered to be a poor indicator of disease risk (Biggerstaff, 2000); none of the above mentioned decision rules exceeded this limit for those participants with a T-score $\leq$ -1.0. Those surveys that had high sensitivity levels, hence selecting the majority of participants with low T-scores, unfortunately had lower specificity levels, which would not allow health professionals to spend more time on education with at-risk individuals. Both the ORAI and the NOF (scored at 3) selected 100% of women with a T-score $\leq$ -2.0, while ruling out 60%-61.5% of the population with T-scores above this level. Each of these surveys was effective as a decision rule in women with severe osteopenia or osteoporosis, which is consistent with findings in older women (Cadarette et al. 2000, Cadarette et al 2001). However, as the goal of osteoporosis prevention is to also educate men and women at risk who might not already have osteoporosis or severe osteopenia, it is questionable whether either of these instruments would be practical in the clinical or public health arenas.

The SCORE tool did place a larger emphasis on age, thereby eliminating all of the study participants from risk identification and resulting in poor sensitivity. Prior studies indicate that in older women, the SCORE has high sensitivity but poor specificity rates (Cadarette et al. 1999, Cadarette et al. 2001, Von Muhlen et al. 1999). Although the NOF guidelines are effective in older women when using a score of one to identify high risk participants (Cadarette et al. 2001, National Osteoporosis Foundation 1998), the NOF survey (scored at 1) was a poor indicator of low BMD risk in young adults. Participants also had to seek clarification to several of the survey's questions, including definitions of physically active behavior and dietary habits. This particular survey tool could possibly be more effective if the terminology was more clearly defined and a scoring system implemented to weight each question.

Overall, none of the decision rules effectively identified those young adults at risk for osteoporosis who already had T-scores $\leq$ -1.0. No prior research has evaluated these surveys in a young cohort. This suggests the need for the development and validation of such an instrument. Screening tools often serve to enhance awareness of a potential problem for consumers (Nickols-Richardson et al. 2002). Providing young men and women with a quick, simple tool that notifies them of a risk for poor bone health could enable clients to become proactive in personal health promotion. In addition, an effective decision rule could be used in physician offices and health fairs to screen for those persons who need additional bone health education. As time spent with a health professional for each individual is often limited, such a tool could allow for more efficient, cost-effective healthcare.

Future Research

Osteoporosis can be considered a pediatric disease, as health practices in childhood significantly affect bone health later in life. Further research is needed to investigate the frequency of bone health education with younger patients of varying ethnicities and economic background to determine which populations are most in need of such education. In addition, investigation is warranted to determine which educational methods are most effective to promote the need for osteoporosis prevention with health professionals in a variety of clinical and public health settings. Medical students, in particular, should receive such education as they often do not receive information regarding the effects of medical nutrition therapy in medical ailments.

Results from this research also indicate the need to develop and validate simple survey tools for use in adults under age 40. Such an instrument would aid health professionals in detecting which patients require additional bone health education, thereby potentially decreasing individual fracture risk as one ages. This tool should also be studied in clinical and public health applications to evaluate its utility in these settings.

Osteoporosis continues to be a significant public health problem that can interfere with the quality of life for those individuals with the disease. In addition, osteoporosis-related healthcare costs will continue to rise as the general population ages, unless early prevention efforts are emphasized in daily medical practice. Health professionals armed with educational resources and survey tools could significantly reduce the number of elderly persons diagnosed with osteoporosis tomorrow by focusing on prevention in younger adults today.

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APPENDIX A

Decision Rules

Subject # ____ Male _____ Female _____

National Osteoporosis Foundation (NOF) Survey

Answering the following questions can help you determine whether you may be at risk for osteoporosis.

1. Do you have a small, thin frame and /or are you Caucasian or Asian? ____

2. Are you a postmenopausal woman? ____

3. Have you or a member of your immediate family broken a bone as an adult? ____
   a. you _____
   b. family member _____

4. Have you had an early or surgically-induced menopause? ____

5. Have you been taking high doses of thyroid medication or high or prolonged doses of cortisone-like drugs for asthma, arthritis or other diseases? ____

6. Is your diet low in dairy products and other sources of calcium? ____
   (less than 3 servings daily)

7. Are you physically inactive? ____
   (less than 2.5 hours in the last 7 days)

8. Do you smoke cigarettes or drink alcohol in excess? ____
   (average of greater than 2 drinks daily)

Subject # _____ Male _____ Female_____

OSTEOPOROSIS RISK ASSESSMENT INSTRUMENT (ORAI)

Please check the column that is most appropriate.

Variable	Yes	No	Score
Age in years			
≥ 75	___	___	
65-74	___	___	
55-64	___	___	
≤ 54	___	___	
Weight in kilograms			
‹ 60 (132 pounds)	___	___	
60-69 (132 – 152 pounds)	___	___	
≥ 70 (154 pounds)	___	___	
Current estrogen use	___	___	

Subject # _____ Male _____ Female _____

SCORE Sheet (Osteoporosis Survey)

Answering the following questions can help you determine whether you may be at risk for osteoporosis.

1. What is your current age? ____

2. What is your race or ethnic group (check one)?
    a. Black
    b. Caucasian
    c. Hispanic
    d. Asian
    e. Native Canadian/First Nation
    f. Other

3. Have you ever been treated for, or told you have rheumatoid arthritis? ____

4. As an adult, have you experienced a fracture (broken bone) at any of the following sites? (Please provide an answer for each of the three sites noted)
    a. Hip _____
    b. Rib _____
    c. Wrist _____

5. Do you currently take or have you ever taken estrogen? (Examples include: Premarin, Estraderm, Estring, Estrace, Ogen) ____

6. What is your current weight in pounds? ____

Vitae

Amanda Lynn Willig, RD June 2004

EDUCATION

Virginia Polytechnic Institute & State University (VT), Blacksburg, VA:
M.S. in Community Nutrition expected: June 2004
Dietetic Internship completed: May 2001

Louisiana Tech University (La Tech), Ruston, LA:
B.S. in Nutrition & Dietetics awarded: May 2000

PROFESSIONAL EXPERIENCE

Medical Facilities of America, Inc.:
Corporate Dietitian for Long Term Care and Rehabilitation Facilities: May 2001-May 2004

CONTINUING EDUCATION

University of Alabama – Birmingham (UAB), Birmingham, AL:
PhD in Nutrition Sciences: enrollment expected for August 2004