Family history of osteoporosis (FHO) has been recognized as one of the most important risk factors for osteoporosis development (Iqbal, 2000). The amount of bony tissue present at the end of skeletal maturation, known as peak bone mass, has been identified as a crucial component for osteoporosis prevention (Rizzoli, & Bonjour, 1999; Valimaki et al., 1994). The primary objective of this study was to assess knowledge and perception about osteoporosis and risk reducing behaviors of female college students with family history of osteoporosis in comparison with those without FHO. The secondary purpose of this study was to compare modifiable risk factors between the two groups. Inclusion criteria was limited to female college students enrolled at Kent State University in spring 2016 semester ages 18 and older. Family history was determined by self-reported data from participants indicating a FHO or fragility fractures in first- or second-degree relatives. Analysis of the data revealed that 95 students had FHO, making up 16.4% of the sample. Results showed there were significant differences in general knowledge and modifiable risk factors of osteoporosis, and risk perception between female college students with FHO and female college students without FHO (P≤0.05). However, no significant differences in perception in risk reducing behaviors and modifiable risk factors were noted between the two groups (P≥0.05). Future studies with
a more consistent method of recording calcium intake and including calcium/vitamin supplementation questions are needed to reconfirm the findings of this study.
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CHAPTER I
INTRODUCTION

Osteoporosis, also known as porous bone, is a common progressive metabolic skeletal disorder that is characterized by decreased bone strength, low bone mass, deterioration of bone tissue, and increased risk of sudden and unexpected fractures in any life stage, but especially in postmenopausal women and the geriatric population (Cleveland Clinic, 2012; Davey, 2012; Janiszewska, Kulik, Dziedzic, & Zolnierczuk-Kieliszek, 2015; Siris et al., 2014). This silent chronic condition affects more than 75 million individuals in the US, Europe, and Japan, 30% of postmenopausal Caucasian women in the U.S., and 200 million women worldwide (Cleveland Clinic, 2010a; Ediriweera de Silva et al., 2014; Janiszewska et al., 2015; World Health Organization [WHO], 2004). Detrimental consequences of osteoporosis include fractures, becoming bedridden, pain, relocation, and social isolation (National Osteoporosis Foundation [NOF], 2014; WHO, 2004; Burge, Dawson-Hughes, Solomon, Wong, & Tosteson, 2006). Annually, 8.9 million osteoporotic related fractures occur worldwide (WHO, 2004). Hip fractures, a common site of osteoporotic fractures are the leading cause of mortality, morbidity, and health care related costs in the geriatric population (Burge et al., 2006). Currently, worldwide approximately 1.6 million hip fractures occur annually. This number is said to increase to 6.3 million by the year 2050 (Ediriweera de Silva et al., 2014).

Due to the progressive silent nature of this disease, osteoporosis is clinically under recognized and untreated and is largely preventable through diet, exercise, and
social behaviors (Lin, & Lane, 2004; Fulgoni, Keast, & Lieberman, 2015). In order to combat this disease, risk reducing/preventative measures of osteoporosis should be taken from years of puberty through young adulthood, and until the age of 30 to obtain the highest potential peak bone mass (PBM) (Cleveland Clinic, 2010a; Ediriweera de Silva, 2015; Siris et al., 2014). PBM, which accounts for more than half of the variability of adult bone mass, is defined as the amount of bony tissue present at the end of skeletal maturation is affected by various factors such as genetics, gender, ethnicity, calcium intake, physical activity, and smoking status (Valimaki et al., 1994; Rizzoli, & Bonjour, 1999; Rabinovich, 2004; Walker, Novotny, Bilezikian, & Weaver, 2008). As college enrollment continues to increase with female enrollment and 18-24 year old population accounting for a majority of college students, a focus on increasing PBM is critical (Fast facts: Back to school statistics, n.d.).

Furthermore, the link between perception and behavior has been well discovered in the world today (Dijksterhuis, & Van Knippenberg, 1998). In terms of osteoporosis, research has demonstrated a relationship between risk perception and family history of osteoporosis (FHO) and knowledge of osteoporosis, and risk reducing behaviors (Clark, & Lavielle, 2015; Blalock et al., 1996). However, a majority of women underestimate this disease, tend to have lowered perceived susceptibility, and below average knowledge of osteoporosis (Hsieh et al., 2001; Ediriweera de Silva et al., 2014).
Statement of the Problem

Calcium intake is correlated with bone mineral mass at every age, but is known to be most important from childhood to early adulthood due to maximal PBM accrual (Cleveland Clinic, 2010a; Valimaki et al., 1994). Typical traditional college student attendance occurs during young adulthood, a period of life characterized by youth gaining independence from their parents (Hermon, & Davis, 2004). This period of life is also where eating habits develop and continue into adulthood. A review of dietary intake among college students reveals a diet that is excessively high in total fat, saturated fat, cholesterol, and sodium, and inadequate in healthful fruits, and vegetables (Haberman, & Luffey, 1998). In addition, low consumption of milk and excessive consumption of soda among the college population is a nutritional concern. Previous data among adolescents and young adults has revealed a significant trend between increased soda consumption and decreased milk intake (Wyshak, 2000; Forshee, & Storey, 2003). In addition, caffeine consumption is found to be the highest among females’ ages 19-30 years of age, and a high prevalence of vitamin D deficiency is also seen among this population which is known to significantly decrease calcium absorption (Bailey et al., 2014; Sharif, & Rizk, 2011).

Based on a body of research, a lack of knowledge and perceived susceptibility of osteoporosis among various female populations has been observed over the past years (Ungan, & Tumer, 2001; Ediriweera de Silva et al., 2014). A study conducted by Ediriweera de Silva et al. (2014) found 40.8% of young female medical students in Sri Lanka
Lanka had poor knowledge related to osteoporosis, and gaps in knowledge were also observed in terms of risk factors, protective factors and the nature of the disease. Perceived susceptibility for the disease was only considered to be high among 13.9% of the participants. In addition, this study also found that risk reducing behaviors such as calcium intake and physical activity were also inadequate among participants.

In addition, past studies have shown that individuals with an increased risk, such as family history of chronic diseases participate in risk reducing behaviors and diet modifications. A study evaluating family history and preventative behaviors of cardiovascular disease found that individuals with a positive family history of cardiovascular disease were more engaged in preventative behaviors such as aspirin use, cholesterol testing, and consuming foods containing less fat content (McCusker, Yoon, Gwinn, Malarcher, Neff, & Khoury, 2004). However, studies regarding individuals with FHO, one of the most important risk factors of osteoporosis, and risk reducing behaviors do not exist among the female college population.

**Purpose Statement**

The purpose of this study was to assess knowledge and perception about osteoporosis and risk reducing behaviors of female college students with female history of osteoporosis in comparison with those without family history of osteoporosis. The secondary purpose of this study was to compare modifiable risk factors between the two groups.
Hypotheses

H₁ = There is a difference in osteoporosis knowledge between female college students with family history of osteoporosis compared to their counterparts

H₂ = There is a difference in risk perception of developing osteoporosis between female college students with family history of osteoporosis as compared to their counterparts

H₃ = There is a difference in perception in risk reducing behaviors of osteoporosis between female college students with family history of osteoporosis as compared to their counterparts

H₄ = There is a difference in modifiable risk factors of osteoporosis between female college students with family history of osteoporosis as compared to their counterparts

Operational Definitions

College female students- undergraduate and graduate female students’ ages 18-30 years old enrolled part time or full time at Kent State University during the 2015-2016 academic year.

Family history- diagnosis of osteoporosis and/or hip fracture of first-degree relatives and second-degree relatives.

First-degree relative- exclusive to biological parents and full blooded siblings.

Second-degree relative- exclusive to grandparents and aunts on the maternal side.
Knowledge of osteoporosis-includes general knowledge of the disease, who the disease predominantly affects, and risk factors associated with the disease as measured through a series of questions in the questionnaire.

Risk perception of osteoporosis- participants perceived risk of developing osteoporosis.

Risk reducing behavior of osteoporosis-behaviors include engagement in physical activity, adequate calcium intake, abstinence from smoking, and minimum alcohol, soda, coffee, and energy drink consumption.
CHAPTER II
REVIEW OF LITERATURE

Definition of Osteoporosis

According to World Health Organization, osteoporosis is defined as a skeletal disease characterized by low bone mass and microarchitectural deterioration of bone tissue with a consequent increase in bone fragility and susceptibility to fracture (Kanis, 1994). In literal translation the term osteoporosis implies "porous bone", a defining characteristic of the disease (Cleveland Clinic, 2012).

Major Affected Population

Although this disease is most prominent in postmenopausal women and geriatric population, osteoporosis is also known to be a pediatric disease with a geriatric outcome, due to the fact that inadequate bone growth in early life greatly raises the risk of an individual’s risk of developing osteoporosis later in life (Janiszewska et al., 2015; Golden, 2000).

Basic Mechanism

The basic mechanism on which the disease transpires is through a greater amount of degrading bone material and structural properties, paired with a lesser amount of bone replacement that occurs over time (Seeman, 2003). Subsequently, the negative balance in the bone modeling process causes reduction of bone density, bone loss, cortical thinning and porosity, trabecular thinning, and loss of connectivity (Seeman, 2003; Russu, Rusu, Ioniuc, & Gotia 2014).
General Clinical Characteristics

Due to the silent progressive nature of this disease, osteoporosis is clinically undertreated and under recognized until it manifests in the form of a fracture (Lin, & Lane, 2004; Christenson, Jiang, Kagan, & Schnatz, 2012). Osteoporosis related fractures can occur at any skeletal site, but is most commonly known to affect the wrist, hip, and spine causing significant morbidity and mortality (Burge et al., 2006). In addition, individuals with osteoporosis face substantial social and health care related costs (Burge et al., 2006; Janiszewska et al., 2015).

Epidemiology/Prevalence of Disease

Chronic diseases, such as cardiovascular disease, chronic respiratory disease, and diabetes, are diseases characterized by long duration, slow progression, and inability to be transmitted person to person (World Health Organization [WHO], 2015). Thirty-eight million deaths annually with 16 million deaths occurring before age 70 can be attributed to chronic diseases (WHO, 2015). With the large proportion of the population ageing, increases in the prevalence of chronic diseases are observed and pose a global health concern. In 2005, in the U.S. 133 million individuals had at least one chronic disease and 63 million individuals had multiple chronic diseases. It is estimated by 2020, 157 million Americans will have at least one chronic disease and 81 million will have multiple chronic diseases (Bodenheimer, Chen, & Bennett, 2009).
Estimated Increase in Prevalence

Osteoporosis is one of the 15 most common chronic diseases identified by Medicare and Medicaid services in 2010, affecting more than 75 million individuals in the US, Europe, and Japan, and affecting 200 million women worldwide (WHO, 2004; Janiszewska et al., 2015; Centers for Medicare & Medicaid Services (CMS), 2012). Approximately, 54 million Americans age 50 and older are currently affected by osteoporosis and low bone density. Assessment of the data also suggests if the incidence of osteoporosis and low bone mass continues at a steady rate then by 2030, a 29% increase in the osteoporosis and low bone mass will be seen as compared to 2010, as well as a dramatic increase in fracture incidents (National Osteoporosis Foundation [NOF], 2014a).

Annually, 8.9 million osteoporotic related fractures occur worldwide, most commonly at sites of the hip, wrist, and spine (Burge et al., 2006; WHO, 2004). Out of these most common sites, hip fractures are the leading cause of mortality, morbidity, and health care related costs in the geriatric population (Burge et al., 2006). Statistically, approximately 20% of individuals who incur an osteoporotic hip fracture die within a time period of a year following the fracture (Gropper, & Smith, 2013). Currently, worldwide approximately 1.6 million hip fractures occur annually. This number is said to increase to 6.3 million by the year 2050 (Ediriweera de Silva et al., 2014).
Medical Costs

In 2005, the direct medical costs related to osteoporotic fractures was estimated to be 17 billion dollars, and 19 billion dollars if prevalent fractures resulting from low bone density was accounted for. This number is projected to increase to 25.3 billion dollars annually by 2025, with an estimated increase in osteoporotic related fractures by 50 percent (Burge et al., 2006).

Other Detrimental Consequences of Osteoporosis

Besides increased risk of fractures, this skeletal disorder is also known to cause further detrimental consequences to individuals such as becoming bedridden, pain, relocation to a nursing home facility, social isolation, and other serious health problems, which can be lethal to the geriatric population (NOF, 2014; WHO, 2004). In fact 33% of individuals who incur an osteoporotic hip fracture are relocated to a nursing home facility within the year of the fracture, and an additional 17% of individuals are unable to resume their previous lifestyle prior to the fracture (Gropper, & Smith, 2013). In recent past decades the increasing knowledge obtained about osteoporosis has shown that this disorder is preventable, but it is still underdiagnosed and treatment and preventive measures still remain below standards (Siris et al., 2014; WHO, 2004).

Bone Metabolism

Bone, a connective tissue typically consists of bone tissue and other tissues such as hemopoeitic tissue, adipose tissue, blood vessels and nerves (Ross, & Pawlina, 2006).
Two-hundred and six bones provide the basis of the human skeleton (Brandi, 2009). This anatomic entity serves as a structural support for vital organs such as the heart, protection for internal organs such as the brain, attachment positions for muscles, tendons, and ligaments, a mineral reserve for key micronutrients such as calcium and phosphorus, and a trap for harmful substances such as lead (Brandi 2009; Lian, Gorski, & Ott, 2004; Byrd-Bredbenner, Moe, Beshgetoor, Berning, 2013).

**Bone Structure**

The skeleton is composed of two primary types of bone, cortical and trabecular (Brandi, 2009). Cortical bone also referred to as compact bone form the shaft of long bones and composes outer surfaces of flat bones creating a protective shell (Brandi, 2009; Byrd-Bredbenner et al., 2013). This type of bone is metabolically inactive and composes 75-80% of the skeletal body is characterized by its harness and density (Byrd-Bredbenner et al., 2013; Gropper, & Smith, 2013). Trabecular bone on the other hand, is made up of a light, but firm arrangement of spongy rods, plates, and spines and is metabolically active under normal circumstances (Byrd-Bredbenner et al., 2013; Gropper, & Smith, 2013). This type of bone provides strength reinforcement to the end of long bones, in the spinal column, and in the inner surfaces of flat bones to help the skeletal structure endure mechanical stresses of daily activities such as standing (Brandi, 2009; Lian et al., 2004). Trabecular bones also referred to as spongy or cancellous bone are main sites of osteoporotic related fractures (Brandi, 2009; Lian et al., 2004; Riggs, & Melton, 1992).
Bone Architecture

The bone composite is a heterogeneous material which is constituted of inorganic, organic and water constituents (Henrikson, Kaye, & Mazurkiewicz, 1997; Boskey, 2013).

Inorganic constituent. The inorganic mineral component in bone is predominantly made up of hydroxyapatite which makes up approximately 85% of the bone mineral component, and has the greatest contribution to bone mass in relevance to the organic and water constituents (Boskey, 2013; Henrikson et al., 1997; Byrd-Bredbenner et al., 2013). Hydroxyapatite is formed by small lattice like crystals of calcium and phosphorus, and has a high surface area to volume ration (Byrd-Bredbenner et al., 2013; Currey, 2002). This mineral composition provides bones with durability allowing it to withstand pressures of bending and compression (Byrd-Bredbenner et al., 2013). Hydroxyapatite also functions to bind with collagen fibers, a protein that makes up half of the human entity and is a part of the organic component found in bones which allow the bone to be durable and flexible at the same time (Byrd-Bredbenner et al., 2013; Currey, 2002).

Organic constituent. Twenty to twenty-five percent of bone mass is attributed to the organic component (Kaufman, 2008). This component is predominantly composed of type 1 collagen, a protein fiber which makes up 90% of the bone matrix and is also shared in areas of the body such as the skin, tendon, and dentin (Boskey, 2013; Byrd-Bredbenner et al., 2013; Currey, 2002). The remaining frame work of the organic...
material is made up of fibronectin, approximately 5% of noncollagenous proteins, and approximately 2% lipids (Boskey, 2013).

Type I collagen is a structural protein found in the bone matrix which provides bone with its shape and size as well as flexibility and strength against tension (Kaufman, 2008; Byrd-Bredbenner et al., 2013; Gropper, & Smith, 2013). It also serves as a template for deposition of bone minerals such as hydroxyapatite, and preserves the extracellular matrix (Boskey, 2013; Byrd-Bredbenner et al., 2013). Structurally, type 1 collagen is a left-handed triple helical molecule composed of a set of identical amino acid chains, usually a glycine-X-Y, with X most commonly being proline and Y being hydroxyproline at times, and an individual amino acid chain which is different (Boskey, 2013; Currey, 2002). The helical structure is influenced by vitamin C and is also referred to as a tropocollagen which clusters to form the collagen microfibrils on ribosomes (Currey, 2002; Gropper, & Smith, 2013). Tropocollagen chains are held together by hydrogen bonds which later cluster together to form fibrils (Currey, 2002). A key distinctive feature of type 1 collagen is its ability to crosslink, which consecutively gives rise to lattice like crystals and provides stabilization of protein molecules (Boskey, 2013; Stipanuk, 2006). This defining structural ability allows collagen to perform its key functions in bone. Two types of cross links are observed in the bone by collagen, enzymatic and non-enzymatic (Boskey, 2013). Enzymatic cross-links are those formed by enzymatic activity and are thought to enhance mechanical strength, but also affected by nutrient deficiencies (Boskey, 2013; Stipanuk, 2006). Non-enzymatic cross-links on the other hand, are those that are formed by glycation and are thought to be elevated in an
uncontrolled diabetic situation and in oxidative stress when end-products show advanced glycosylation. Both forms of crosslinks are known to be increased with age, altered as disease progresses, and elevated in quantity in osteoporotic individuals (Boskey, 2013).

Noncollagenous proteins are primarily constituted from the small integrin-binding N-glycosylated, small leucine-rich proteoglycans, gamma-carboxyglutamic acid, and small secreted cysteine-rich protein families. This small component of the extracellular matrix plays a key role in preventing fractures by interacting with collagen fibrils and functioning to hold together bone as a whole. Previous studies have demonstrated a link between reduced noncollagenous proteins and osteoporotic bone (Boskey, 2013).

Lipid a minor constituent of the organic component plays an important role in cell function, encircling the cell body, regulating ions and signaling molecules. Fibronectin is another structural protein found in bone matrix and functions to aim the initial deposition of collagen fibrils and to maintain the collagenous extracellular matrix (Boskey, 2013).

**Extracellular matrix of bone.** In the extracellular matrix of bone water plays a key role in filling the pores, interacting with collagen fibrils, and binding to mineral crystals (Boskey, 2013). Bone, a specialized connective tissue consists of cells and extracellular matrix (Ross, & Pawlina, 2006). Ninety-eight percent of bone matrix is attributed to the organic and water components while the small remaining portion (2%) of the bone matrix is made up of bone cells (Kaufman, 2008). These bone cells are known as osteoprogenitor cells, osteoblasts, osteocytes, and osteoclasts (Kaufman, 2008; Ross, & Pawlina, 2006).
Major Nutrients for Bone Health Excluding Calcium and Vitamin D

Besides calcium minerals such as phosphorus, magnesium, potassium, sodium, fluoride sulfur and vitamin K are essential for optimal bone health (Byrd-Bredbenner et al., 2013). Phosphorus is the second most commonly mineral found in the body and bone making up approximately 1.2% of body weight more than 50% of bone mineral mass (Angelo, 2012; Gropper, & Smith, 2013).

Phosphorus

Phosphorus serves key functions in bone mineralization, energy storage, energy transfer, and in maintaining pH balance (Gropper, & Smith, 2013). In bone this mineral accounts for 85% of total body phosphorus and plays a role in bone forming cells known as osteoblasts which is greatly dependent on phosphate concentration in the bone matrix (Angelo, 2012; Raggatt, & Partridge, 2010; Gropper, & Smith, 2013). In the diet phosphorus is found in foods that are high in protein such as meats, milk, eggs, and cereal (Stipanuk, 2006).

Magnesium

Magnesium is the 6th most abundant mineral found in body and is predominantly found in the skeletal system, approximately 50-60% of the body's total magnesium is found in bone (Angelo, 2012; Gropper, & Smith, 2013). In the skeletal system, magnesium is predominantly found with hydroxyapatite providing size and structural support of the lattice-like crystals of hydroxyapatite, and to a lesser extent on the surface...
of bone in an unstructured form (Angelo, 2012; Byrd-Bredbenner et al., 2013; Gropper, & Smith, 2013).

**Sodium**

In the body approximately 30% of the sodium found is located on the surface of bone crystals (Gropper, & Smith, 2013). Sodium plays an important role in maintenance of fluid balance, nerve transmission, and muscle contractions and although does not have a direct role on bone health it thought to negatively affect bone health by increasing urinary calcium excretion with excessive sodium intake (Gropper, & Smith, 2013; Angelo, 2012). The mechanism proposed includes factors of excessive sodium intake which increases urinary calcium output and a low calcium diet which will leave calcium in a negative balance (Angelo, 2012).

**Potassium**

Potassium is a major intracellular cation which functions in the contractility of muscles, impulsiveness of nerve tissue, and for homeostasis of pH and electrolytes in the body (Gropper, & Smith, 2013). Similar to sodium, potassium does not have a play a direct role in bone health, but rather an opposing and protective role. In contrast to sodium, excessive potassium decreases urinary calcium excretion, and provides protection against acidosis (Gropper, & Smith, 2013).
Fluoride

Fluoride is a nonessential nutrient found mainly in bones and teeth due to its high affinity for calcium (Angelo, 2012; Gropper, & Smith, 2013). Approximately 99% of the body's total fluoride concentration is inbound in bones and dentin. In bone fluoride is present in a shapeless form as well in a crystalized state inside of hydroxyapatite (Gropper, & Smith, 2013). Similar to phosphate, fluoride has a direct effect on the osteoblasts, stimulating bone formation (Angelo, 2012).

Vitamin K

In bone, vitamin K plays a major role as a cofactor for the carboxylation reaction of gamma-carboxyglutamic acid-rich (GLA) proteins such as osteocalcin, matrix GLA protein, protein S, and Gas-6 found in bone tissue (Angelo, 2012). This enzymatic reaction allows for modification of GLA proteins to allow them to bind to calcium and facilitate bone mineralization (Angelo, 2012; Gropper, & Smith, 2013). Previously, an inverse relationship was observed between undercarboxylated serum osteocalcin concentrations and bone mineral density in the first ten years of menopausal women (Gropper, & Smith, 2013).

Bone Cells

Bone is saturated and lined by various kinds of specialized cells, known as bone cells (Currey, 2002). These bone cells are known to for their importance for bone biology at the cellular level and include osteoprogenitor, osteoblasts, osteocytes, and
osteoclasts (Ross, & Pawlina, 2006). These specialized bone cells each have a unique function and process, and function in bone growth (Moini, 2016).

**Osteoprogenitor Cells**

Osteoprogenitor cells, also known as osteogenic cells, are osteoblast precursor cells that are derived from mesenchymal stem cells from the bone marrow (Ross, & Pawlina, 2006; Moini, 2016). These specialized cells have the capability to differentiate in fibroblasts, osteoblasts, adipocytes, chondrocytes, and muscle cells. In order for a resting osteoprogenitor cell to differentiate into an osteoblast the protein core binding factor alpha-1 is needed (Ross, & Pawlina, 2006). These renewable cells can be found almost anywhere on and in bone, including in the layer on the outside of bone called the periosteum, in the endosteum which is inside marrow cavities, the Haversian canals, and the Volkmann's canals (Ross, & Pawlina, 2006; Currey, 2002). Once differentiated into an osteoblast this specialized cell has the capability to secrete bone matrix (Ross, & Pawlina, 2006). In postnatal life, osteoprogenitor cells persist as quiescent osteoblasts or otherwise known as bone-lining cells. These cells are reactivated in adulthood during the repair of bone related injuries and control the movement of ions between the bone and the body (Bonakdarpour, Reinus, & Khurana, 2010; Currey, 2002).

**Osteoblast Cells**

Osteoblast cells are secretory cells that arise from osteoprogenitor cells (Stipanuk, 2006; Ross, & Pawlina, 2006). They are immature bone cells that are responsible for bone formation and resorption, calcification bone matrix (Kaufman, 2008; Ross, &
Pawlina, 2006; Stipanuk, 2006). Their function is controlled by endocrine, paracrine, and autocrine factors which express receptors for parathyroid hormone, estrogen, 1,25 dihydroxyvitamin D, and numerous regulatory factors (Kaufman, 2008; Pivonka, Buenzli, & Dunstan, 2012). This specialized cell secretes type I collagen, as well as bone matrix proteins such as calcium binding proteins, multiadhesive glycoproteins, osteopontin, thrombospondin, proteoglycans, and alkaline phosphatase. These components compose the osteoid which is the initial unmineralized bone (Ross, & Pawlina, 2006). Once osteoid deposition occurs and surrounds the osteoblast, the cell then becomes an osteocyte or the cell processed to undergo cell death (Ross, & Pawlina, 2006; Pivonka et al., 2012).

Osteocyte Cells

The most numerous cells in bone are the osteocyte (Byrd-Bredbenner et al., 2013). An osteocyte is a mature biochemically active bone cell found in the bone matrix within a lacuna (Ross, & Pawlina, 2006; Pivonka et al., 2012; Byrd-Bredbenner et al., 2013). This specialized cell can maintain bone matrix which ultimately aids to maintain calcium homeostasis by synthesizing new matrix, or degrading pre-existing bone matrix (Ross, & Pawlina, 2006). These mature bone cells also communicate with adjacent osteocytes and with bone-lining cells through gap junctions, a long dense and interconnecting canaliculæ network (Pivonka et al., 2012; Ross, & Pawlina, 2006). This process is critical for the osteocyte to respond to mechanical forces that affect the bone, a process called mechanotransduction (Kaufman, 2008; Ross, & Pawlina, 2006).
Osteocytes also communicate with distant osteoblasts, pericytes of blood vessels, and other bone cells indirectly through signaling molecules (Ross, & Pawlina, 2006).

**Osteoclast Cells**

Osteoclasts are derived from the fusion of mononuclear hemopoietic progenitor cells under the influence of various cytokines and form in close correlation with stromal cells in the bone marrow (Ross, & Pawlina, 2006). These highly specialized bone cells are known for their bone-destroying function and are large and multinucleated structurally (Currey, 2002). Osteoclastic activity is dependent on the stimulation of the parathyroid hormone often with 1,25 dihydroxyvitamin D (Byrd-Bredbenner et al., 2013). In order for osteoclasts to become bone-resorbing cells they undergo an activation process in which the osteoclast becomes highly polarized and exhibits specialized regions on its cell when resorbing bone material. These regions are known as ruffled border which is in direct contact with the bone, clear zone a circular perimeter of cytoplasm neighboring the ruffled border that distinguishes the area of bone that is undergoing absorption, and the basolateral region that operates in exocytosis of digested substances. Bone resorption then proceeds by protons and lysosomal hydrolases which degrade proteins which compose the bone matrix. Once the resorption process is complete the osteoclasts undergo programmed cell death known as apoptosis (Ross, & Pawlina, 2006).

**Bone Modeling and Remodeling**

Bone is a living tissue that undergoes constant change throughout an individual's life span (Hadjidakis, & Androulakis, 2006). Bone development and maintenance occurs
at every bone in the body and is supported by two main processes: bone modeling and bone remodeling (Raggatt, & Partridge, 2010; Clarke, 2008).

**Bone Modeling**

Bone modeling is accountable for growth and mechanically stimulated alteration of bone which occurs during childhood and adolescence period (Raggatt, & Partridge, 2010; Clarke, 2008). Hormones involved in bone maintenance and homeostasis of minerals include the growth hormone, thyroid hormones, sex hormones, adrenocorticoid hormones, 1,25 dihydroxyvitamin D, calcitonin, and parathyroid hormone (Byrd-Bredbenner et al., 2013). The bone modeling process is governed by bone formation and bone resorption involving osteoblasts and osteoclasts, respectively (Raggatt, & Partridge, 2010; Stipanuk, 2006). The activity of osteoblasts determines the rate of deposition of bone matrix, while the activity of osteoclasts determines the rate in which bone is broken down (Stipanuk, 2006). Bone formation, also known as ossification occurs at the epiphyseal growth plate which is located between the middle segment of the bone known as the shaft, and the end of the bone which is known as the epiphysis (Byrd-Bredbenner et al., 2013; Widmaier, Raff, & Strang, 2014). The epiphyseal growth plate actively proliferates cartilage, allowing the bone to grow towards the ends of its structure (Widmaier et al., 2014). Bone resorption on the other hand occurs on the surface of pre-existing bones and degrades bone moving towards the middle (Gropper, & Smith, 2013). In this process osteoclasts break down bone and release minerals consequentially transferring calcium from the bone to the plasma (Byrd-Bredbenner et al., 2013). Bone
formation and resorption in the bone modeling process is not strictly coupled, and may occur in different distant anatomical locations (Raggatt, & Partridge, 2010; Clarke, 2008). Both of these bone processes also allows for homeostasis of calcium and phosphorus concentration in the plasma (Byrd-Bredbenner et al., 2013). The bone modeling process is uncommon in adults, but may be seen to be increased in diseases such as hypoparathyroidism, renal osteodystrophy, and treatment that involve anabolic means (Clarke, 2008).

**Bone Remodeling**

In comparison with the bone modeling process, bone remodeling is a fairly complex and highly coordinated process which utilizes osteoblasts, osteoclasts, osteocytes, immune T-cells and B-cells, megakaryocytes, and osteomas (Raggatt, & Partridge, 2010). A structure known as the basic multicellular units is formed in this process from clusters of osteoblasts and osteoclasts (Raggatt, & Partridge, 2010). This temporary structure regulates the bone remodeling process (Chowdhury, 2014; Raggatt, & Partridge, 2010). The intricate bone remodeling process functions to allow bones to grow normally maintaining its bone mass, maintain extracellular calcium concentration, and repair and replace microdamaged bones which are vital procedures for the maintenance of bone health (Byrd-Bredbenner et al., 2013; Raggatt, & Partridge, 2010; Angelo, 2012). The bone remodeling process operates by resorbing old bone first and then replacing it with newly synthesized bone matrix and constituents to form new bone. This process begins before birth and continues through one's lifespan (Clarke, 2008). In
general, by the age of 40, bone resorption is greater than bone deposition, leading to loss of bone mass to up to 25% depending on an individual's longevity (Byrd-Bredbenner et al., 2013). The bone remodeling process is also known to peak in perimenopausal and early postmenopausal women, and continues at an accelerated rate in postmenopausal women as compared to premenopausal women (Clarke, 2008). In contrast with the bone modeling process, bone remodeling is a coupled process of bone formation and bone resorption meaning that this process occurs in the same anatomical location endorsing the overall integrity of the skeletal structure (Stipanuk, 2006). However, this process is more active in trabecular bone as compared to cortical bone due to a larger surface to volume ration (Hadjidakis, & Androulakis, 2006).

**Five Phases of Bone Remodeling.** Five phases that occur chronologically make up the process of bone remodeling. These phases are activation, resorption, reversal, formation and termination sequentially (Raggatt, & Partridge, 2010). The first phase, activation involves revealing a initiating remodeling signal which puts strain on the bone causing damage to the bone structurally or hormone action (Chowdhury, 2014). Preosteoclast cells in circulation are then transformed into large multinucleated osteoclasts by ratio of receptor activity which includes osteoprotegerin, colony-stimulating factor, parathyroid hormone, 1, 25 dihydroxyvitamin D, and calcitonin (Stipanuk, 2006; Clarke, 2008). The second phase, resorption is the process of which osteoclastic cells are then recruited to anatomical site which expresses cytokines CSF-1, RANKL, and OPG and resorbs old bone material by the action of osteoclasts (Chowdhury, 2014). Termination of the resorption phase occurs by mononuclear cells
once osteoclasts undergo apoptosis (Clarke, 2008). The mononuclear cells present allow for preparation of new bone formation by osteoblasts and signals for their differentiation and migration (Hadjidakis, & Androulakis, 2006). In the third phase, reversal transition of cellular activity is observed. In this phase, osteoblasts and bone matrix are released from the resorption cavities promoting bone formation. Information the osteoid is formed and deposition of hydroxyapatite occurs. Once the quantity of bone that is formed equals the quantity of bone that was resorbed, the formation phase is completed (Chowdhury, 2014). The final phase, termination is also known as the quiescence phase (Burtis, Ashwood, & Bruns, 2012). In this process the osteoblasts slow their production becoming still lining cells and in some cases can also become osteocytes or part of the extracellular matrix (Chowdhury, 2014).

**Peak Bone Mass**

The amount of bony tissue present at the end of skeletal maturation characterizes PBM (Rizzoli, & Bonjour, 1999). In general PBM is considered a major determinant of bone mass later in life, and consequently an important component in prevention of osteoporosis (Valimaki et al., 1994). In fact, it is believed that PBM acquired by the end of the growth phase bares a higher significance as compared to the bone loss that occurs during adulthood. According to mathematical calculations, an increase of 10% in PBM would prolong the onset of osteoporosis by more than a decade (Glorieux, Pettifor, & Juppner, 2012).
Complete PBM is achieved in the late second decade or early third decade of life and is thought to account for more than half of the variability in adult bone mass (Rizzoli, & Bonjour, 1999; Rabinovich, 2004). In general approximately 85-90% of the acquisition of PBM is attained by the age of 18 years for females and 20 years for males (Heaney et al., 2000).

**Factors Affecting Peak Bone Mass**

PBM is predominantly influenced by the genetics of an individual. Genetics account for 80% of the variance of PBM (Valimaki et al., 1994). Although the genes responsible for PBM are unknown a polygenic array of genes is thought to be responsible at this time (Langman, & Trippe, 2010). The remaining 20% of the variance is attributed by environmental factors such as calcium intake, smoking and physical activity during adolescence and early adulthood. Data collected from 264 participants who were originally part of a cardiovascular risk study in the 1980’s when participants were ages 3-18 years old was used for a bone mineral density study conducted in 1991, when the participants were age 20 and over. The use of existing dietary interviews, smoking status, and data pertaining to exercise, as well as new data regarding these factors and dual energy x-ray absorptiometry was used to calculate the results. Results of this study indicated routine physical activity, and abstinence from smoking behaviors were a significant factor in achieving PBM during the adolescent and young adult period of life. Bone mineral density of the neck and calcium intake was also found to be positively correlated among women in this study, rising by approximately 5% in women who had
calcium consumption of 800-1200 mg (Valimaki et al., 1994). A more recent study conducted on females of different races found a significant relationship between young adult bone mass and calcium intake (Wang et al., 2003). Various other studies on females of varied life stages have also shown a positive correlation between calcium intake and bone mineral density (Bonjour et al., 1997; Reid et al., 2006; Matkovic et al., 2007). Differences observed between genders are seen at the onset of puberty in males and females and are attributed to the action of sex steroid hormones (Rizzoli, & Bonjour, 1999; Orwoll, Belknap, & Klein, 2001). In both genders, the female sex steroid hormones are essential for maximal accrual of bone mass, as well as maintenance of bone mass throughout the bone remodeling process (Rizzoli, & Bonjour, 1999).

In general, males undergo puberty maturation later in adolescence as compared to females, allowing for greater acquisition of cortical bone thickness, and bone size which results in greater bone mineral content (Rizzoli, & Bonjour, 1999). In addition, differences between ethnicities are also observed in terms of PBM. The highest PBM between both genders is observed within African American population as compared to their Caucasian, Asian, Hispanic, and Native American counterparts (Walker et al., 2008).

**Life Stages and Bone**

Continuous remodeling of bone tissue by the processes of bone resorption and bone formation occurs throughout an individual’s lifespan. Due to this process the bones consistently undergo changes (U.S. Department of Health and Human Services, 2004).
Childhood and Adolescence

During the child and adolescent phase bone modeling is highly active and is the primary determinant of bone strength. In children this process allows bones to become denser at the trabecular, endocortical, and intracortical surfaces, longer at growth plates and wider at the periosteum which located outside of the bone. This life stage is characterized by a greater amount of bone deposition as compared to bone withdrawal (Langman, & Trippe, 2010).

Early Adulthood

By the beginning of the second decade of life the majority of PBM is attained (Heaney et al., 2000). By the third decade of life complete PBM has been achieved and bone has reached its maximum strength and density (Rizzoli, & Bonjour, 1999; Glorieux et al., 2012). At this point bone has reached a period where remodeling is relatively balanced (Langman, & Trippe, 2010).

Adulthood

As compared to in childhood, the bone remodeling process is the major determinant of bone strength in adulthood. During this phase the trabecular surface of bone is resorbed and new bone is formed (Langman, & Trippe, 2010). This process continues to be relatively balanced until the fourth decade of life where bone resorption surpasses bone formation consequently resulting in bone loss due to a high bone turnover rate (Byrd-Bredbenner et al., 2013; Riggs, & Melton, 1992). Throughout the course of
life, women tend to lose approximately 50% of their trabecular bone, and 30% of their cortical bone. Men on the other hand tend to only lose 30% of their trabecular bone and 20% of their cortical bone (Riggs, & Melton, 1992).

**Menopause**

Menopause usually occurs between the ages of 48-52 and is characterized by the loss of hormones produced by the ovaries, and the termination of the menses cycle, and fertility in women (Byrd-Bredbenner et al., 2013; Ozdemir, Celik, Gorkemli, Kiyici, & Kaya, 2009). This process is coupled with estrogen withdrawal and causes women to rapidly lose bone during the first ten years of menopause due to a dramatic increase in bone resorption as compared to bone formation (Cleveland Clinic, 2012; Riggs, & Melton, 1992). This process that is mediated by osteoclasts can lead to perforation and loss of the trabeculae in spongy bone therefore possibly eliminating bone formation which is mediated by osteoblasts. During the early phases of menopause women experience approximately a third to half of their total bone loss (Riggs, & Melton, 1992). This acceleration in bone loss has caused post-menopausal women to be the primary target of osteoporosis (Christenson et al., 2012). In fact, women are four times more susceptible to this debilitating disease as compared to men (Cleveland Clinic, 2012).

**Pathophysiology of Osteoporosis**

Osteoporosis is a systemic skeletal disease which is characterized by low bone mineral density and deterioration of microarchitecture of bone tissue (Gropper, & Smith, 2013). Although osteoporosis manifests predominately in older individuals,
approximately 60% of the variable risk of the disease is attributed to ability to achieve PBM by early adulthood (Rizzoli, & Bonjour, 1999; Langman, & Trippe, 2010). For this reason, osteoporosis is often referred to as a pediatric disease with a geriatric outcome (Golden, 2000).

**Type 1 Osteoporosis**

There are three main types of osteoporosis. Primary osteoporosis, type 1 osteoporosis, also referred to as hormonal osteoporosis is related to the aging process as well as withdrawal of estrogen in postmenopausal women (Cleveland Clinic, 2010a; Cleveland Clinic, 2012; Gropper, & Smith, 2013). This type of osteoporosis is the most common form of the disease observed in clinical settings and is known to peak through the ages of 51-75 in an individual’s life (Iqbal, 2000; Kamel, 2006). Loss of trabecular bone is prominent in type 1 osteoporosis resulting in vertebrae fractures and Colles’ fractures which occur in the distal radius (Iqbal, 2000; Kamel, 2006). The loss of estrogen in this type of osteoporosis is thought to trigger the parathyroid hormone resulting in calcium resorption from the bone. The disease progresses by a subsequent decrease in the secretion of the parathyroid hormone, production of vitamin D, and calcium absorption (Iqbal, 2000). The frequency of this type of osteoporosis is more pronounced in woman as compared to men, with a 6:1 female to male ratio (Kamel, 2006). Also, in this type of osteoporosis rapid bone loss is observed in menopausal women during the first five years of menopause. During this time women may incur a bone loss of 2-3% per year, and can reach to equal 20% of bone loss that one could incur
during their lifespan (Iqbal, 2000; Coney, 2014). Clinical implications of menopause include a greater risk of fractures, especially at skeletal sites of the hip and vertebrae due to bone loss and decreased bone strength (Coney, 2014; Angelo, 2012). A previous study revealed rates of hip and vertebral fractures increasing linearly with age after 50, the median age when menopause occurs in women (Burge et al., 2006; Byrd-Bredbenner et al., 2013). Osteoporotic fractures along with other gradual changes in bone among menopausal women increase mortality and morbidity rates within this population (Christenson et al., 2012).

**Type 2 Osteoporosis**

Type 2 or senile osteoporosis affects both men and women above the age of 70 years old, but is more pronounced in women affecting twice as many females as compared to males (Kamel, 2006). This type of osteoporosis is usually related to decreased bone formation and decreased kidney action in the elderly population. Due to the decreased action of the kidneys a decline in activation of vitamin D is observed which decreases calcium absorption and therefore increases the action of the parathyroid hormone, which eventually pulls calcium from the bones (Iqbal, 2000). Senile osteoporosis causes loss of trabecular and cortical bone which results in increased risk of fractures of the hip, long bone, and vertebral column (Iqbal, 2000; Gropper, & Smith, 2013).
Type 3 Osteoporosis

Secondary osteoporosis is the result of chronic diseases such as anorexia nervosa or Cushing’s syndrome, medications such as steroids or heparin, nutritional conditions such as calcium deficiency or alcoholism, or lifestyle causes such as tobacco use or athletic amenorrhea (Cleveland Clinic, 2010a). This type of osteoporosis is also referred to as type 3 osteoporosis and is known to affect any age group and both sexes equally. In fact, approximately 40% of osteoporotic fractures seen in the clinical setting are attributed to secondary osteoporosis (Iqbal, 2000).

Signs, Symptoms, and Consequences of Osteoporosis

In general, the first sign of osteoporosis is in the form of a fracture. Until then the disease progresses in a silent manner (Lin, & Lane, 2004). Skeletal fractures are considered the clinical manifestation of osteoporosis, especially at sites of the hip, distal radius, and vertebrae (Cleveland Clinic, 2010a; Gropper, & Smith, 2013). Typically, fractures proceed in increasing prevalence first at skeletal site of the wrist, then the spine, and finally the hip, increasing approximately when the individual is in their 50’s, 60’s, and 70’s respectfully (Cleveland Clinic, 2010a). A study that evaluated the U.S. incidence of fractures by type, gender, age, and race in 2005 found 136,624 women had wrist fractures between the ages of 50-64, composing the highest number of fractures per wrist fracture type among various age groups across the female gender. The incidence of vertebral fractures among this population was seen to dramatically increase in the age group 65-74 and peak in the age group of 75-84 where 142,892 women had vertebral
fractures. Hip fractures also followed a similar trend as vertebral fractures, dramatically increasing among the age group of 75-84, and peaking in the age group 85 and above which accounted for 99,771 hip fractures in 2005 (Burge et al., 2006). Individuals who experience osteoporosis at sites of the vertebrae may experience pain, limited mobility, loss in stature, and kyphosis. Kyphosis, also known as Dowager’s hump, is a hunchback curvature of the spine that reduces the area between the chest and abdomen. Dowager’s hump may result in shortness of breath due to decreased lung capacity, restricted activity, altered anatomy of the abdomen leading to abdominal pain, decreased appetite, and an untimely feeling of satiety (Gropper, & Smith, 2013; Lee, & Nieman, 2013). In addition, individuals with osteoporosis may experience loose or loss of teeth due to loss of spongy bone in the jaw (Gropper, & Smith, 2013).

Personal consequence of osteoporosis that an individual may face due to osteoporosis is loss of freedom due to relocation to a nursing home, depression, pain, immobility, other health issues (Dempster, 2011; NOF, 2014). For instance, roughly 20% of patients with osteoporotic hip fractures necessitate long term nursing home facilities, and a majority of these individuals are not able to recover to their original level of independence prior to their fracture. In addition, individuals with hip fractures suffer a 10-20% increase in risk of mortality within a year of the fracture, and are 2.5 times more likely to develop fractures in the future (Dempster, 2011). A previous study conducted by Johnell and Kanis (2006) revealed in Europe osteoporosis induced disability was greater than disabilities caused by non-communicable diseases such as most cancers, and was equivalent or greater than rheumatoid arthritis and hypertension in relation to
cardiovascular disease. Loss of functionality also accompanies osteoporosis and generally results in emotional and psychological consequences, such as depression (Dempster, 2011).

**Diagnosis of Osteoporosis**

Osteoporosis remains to be undertreated and under recognized due to the silent nature of the disease (Lin, & Lane, 2004). Unlike an array of other chronic diseases, osteoporosis does not typically pose signs or symptoms of the disease until a fracture is present due to the asymptomatic nature of age-related bone loss (Benjamin, Griggs, Wing, & Fritz, 2010; WHO, 2004). Chemical laboratory tests of urine or blood are not good indicators in diagnosis of the disease due to the fact that they are usually not atypical in individuals with osteoporosis (Iqbal, 2000). In general, clinical diagnosis of osteoporosis is made after an individual suffers an acute fracture of the vertebrae, or hip, or by measurement of bone mineral density (Benjamin et al., 2010). Based upon data collected from Caucasian postmenopausal females in 1994 the World Health Organization developed a diagnostic criterion for osteoporosis and osteopenia, the premature state prior to osteoporosis (Benjamin et al., 2010; Gropper, & Smith, 2013).

**Diagnostic Criteria**

A diagnostic criterion is based upon T-scores which compare an individual’s variation from a young adult’s PBM. Normal T-scores for a healthy individual are specified by T-scores above 1.0 standard deviation. T-scores equal to or less than 2.5 standard deviation of young adult PBM on the other hand are indicative of osteoporosis,
while a T-score ranging from 1.0-2.5 SD of young adult PBM are indicative of osteopenia (Benjamin et al., 2010). A single decrease in standard deviation in bone mineral density is estimated to increase fracture risk up to three times (Lee, & Nieman, 2013).

**Bone Mineral Density Testing**

Currently, there is no accurate method of measuring complete bone strength. For that reason, measurement of bone mineral density is widely used for the diagnosis of osteoporosis. Approximately, 60-80% of overall bone strength is accounted for through bone mineral density testing. Although many methods of bone mineral density testing are available such as radiogrammetry, single photon absorptiometry, quantitative computed tomography, and quantitative ultrasound (Lee, & Nieman, 2013).

**Dual energy-X-ray absorptiometry.** The gold standard for diagnosis of osteoporosis as well as osteopenia remains to be through the dual energy-X-ray absorptiometry, also known as DEXA (Lee, & Nieman, 2013; Gropper, & Smith, 2013). This form of low radiation technology functions by combining two X-ray beams at different energy levels examining the individual and calculating percentage of bone mineral density in the spine, hip, and overall body, fat mass, and fat-free mass composition (Gropper, & Smith, 2013; Byrd-Bredbenner et al., 2013). In addition, the DEXA scan can be accomplished in approximately ten seconds making the method convenient for its users (Lee, & Nieman, 2013). However, the DEXA bone density scan does have drawbacks including the expense factor of the equipment, and X-ray exposure,
although it only entails 1-10% of X-ray exposure to subjects as compared to a normal chest X-ray (Gropper, & Smith, 2013).

**Fracture risk assessment tool.** The computer-based algorithm known as the Fracture Risk Assessment Tool, also referred to as FRAX was developed by the World Health Organization in 2008. The use of this algorithm functions to calculate an individual’s ten year fracture probability of major osteoporotic fractures along the hip, spine and wrist as well as the risk of death based on clinical risk factors. In addition, the FRAX model also takes into account geographical location of the individual, and currently there are FRAX models available for 31 countries across the globe. Furthermore, upon review by the U.S. Food and Drug Administration (FDA) the FRAX model was merged with the DEXA scanners allowing FRAX probabilities to be provided simultaneously with the DEXA scan. However, the use of FRAX it is important to note even though many clinical guidelines are incorporating the FRAX model, the use of the model should be used as a reference standard as compared to the gold standard in patient assessment (Kanis et al., 2011).

**Prevention and Treatment of Osteoporosis**

Prevention of osteoporosis is known to have greater success as compared to treatment of osteoporosis due to the fact that bone mass cannot be entirely restored (Iqbal, 2000). Prevention of osteoporosis should occur throughout life by maintaining adequate protein, vitamin A, as well as other vital nutrients such as calcium, vitamin D, phosphorus, magnesium, and many others that support bone health and help build PBM
in early life stages and into the mid 30’s (Byrd-Bredbenner et al., 2013; Gropper, & Smith, 2013; Lee, & Nieman, 2013). Adequate nutrition throughout life has been known to reduce the effects of osteoporosis by half or more, and significantly reduces the rate of morbidity and mortality (Lee, & Nieman, 2013). Regular exercise should also incorporate as a preventative measure of osteoporosis. Exercises such as walking, hiking, running, dancing, tennis, and weight bearing exercises can help to improve an individual’s overall health by increasing muscle strength, coordination, stability and stronger bones in the presence of adequate nutrients such as calcium and vitamin D (Iqbal, 2000). The benefits of regular exercise are discussed more in modifiable risk factors: physical activity.

**Pharmacological Methods**

In addition, postmenopausal women should seek pharmacological treatment should be perused if signs of osteoporosis are observed, including low bone density and especially if more than 1.5 inches of height is lost during the postmenopausal stage of life (Byrd-Bredbenner et al., 2013; Riggs, & Melton, 1992). Medical interventions are predominantly broken down into two categories. These include therapies that reduce the amount of bone resorption, and ones that increase the amount of bone formation (Riggs, & Melton, 1992). These include estrogen, bisphosphonates, selective estrogen receptor modulators, calcitonin, and parathyroid hormone (Byrd-Bredbenner et al., 2013).

**Hormone replacement therapy.** Treatment with estrogen or hormone replacement therapy decreases the disproportion in the bone remodeling process,
subsequently preserving bone mass by decreasing bone turnover by decreasing the bone resorption process by reducing activity of osteoclasts (Byrd-Bredbenner et al., 2013; Riggs, & Melton, 1992; Iqbal, 2000). For this reason estrogen, along with bisphosphonates, and calcitonin are also referred to as antiresorptive agents (Riggs, & Melton, 1992). Administration of estrogen may be done through injection or oral or transdermal means all providing an equal effect when administered in appropriate dosages (Iqbal, 2000). Duration of five to ten years of estrogen therapy is known to significantly lower the risk of osteoporotic fractures, although longer use of this form of treatment may be required due to accelerated bone loss, similar to menopause is associated with discontinuation of estrogen. In some cases, progestin coupled with estrogen has shown to be beneficial in women who experience amenorrhea, or women that have not undergone a hysterectomy. Estrogen therapy is deemed the most effective way to reduce osteoporotic fractures at all major sites, approximately a 50% reduction in osteoporotic fractures has been observed in women at risk of osteoporosis when they began the use of estrogen therapy in early stages of menopause, whereas in women with osteoporosis it has been observed to reduce fractures of the hip, radius, and a greater extend to the vertebrae by up to 50% and increase vertebral bone mass greater than five percent. In addition, long-term form of this therapy has also been observed to significantly reduce the risk of cardiovascular disease, stroke, as well as death incidence from all other natural causes (Riggs, & Melton, 1992; Iqbal, 2000). Although caution should be advise due to the fact long term estrogen use can result in side effects such as
thromboembolism, high blood pressure, blood clots, vaginal bleeding, and breast and endometrial cancer (Iqbal, 2000).

**Bisphosphonates.** Bisphosphonates were introduced in the clinical setting more than 30 years ago (Drake, Clarke, & Khosla, 2008). These agents are a potent non-hormonal form of therapy with a high affinity for bone used in the prevention and treatment of osteoporosis (Iqbal, 2000; Drake et al., 2008). These chemically stable agents derived from inorganic pyrophosphate function by binding to hydroxyapatite and osteoclasts to decrease activity of bone resorption to protect against bone loss and fragility (Drake et al., 2008; Byrd-Bredbenner et al., 2013; Iqbal, 2000). Current research indicates the use of bisphosphonates may also reduce programmed cell death of osteocytes, and osteoblasts. However, more scientific based evidence is needed to support this claim. First generation bisphosphonates such as etidronate, clodronate, and tiludronate did not contain nitrogen whereas second and third generation bisphosphonates such as alendronate, risedronate, ibandronate, pamidronate, and zoledronic acid contain nitrogen side chains. The presence of the nitrogen side chains allows the agent’s antiresorptive potency to increase by 10-10,000 as compared to first generation bisphosphonates (Drake et al., 2008). A previous study including 4,432 women concluded that the use of alendronate reduces risk of all factors, especially at major sites of osteoporosis by 50 percent (Iqbal, 2000). Administration of bisphosphonates is done orally or intravenously in clinical settings often in place of hormonal therapy which has been linked with increased risk of some forms of cancer and heart disease in postmenopausal women (Drake et al., 2008; Byrd-Bredbenner et al., 2013). Suppression
of the bone resorption process is varies on the mode of administration. Oral means are known to suppress the resorption process within three months due to poor absorbability in the GI tract, whereas intravenous methods of administration are known to suppress bone resorption much more readily (Drake et al., 2008). Although rare, side effects include heartburn, musculoskeletal discomfort, nausea, and esophageal, abdominal irritation, and hypovitaminosis D (Iqbal, 2000; Drake et al., 2008). In addition, the use of bisphosphonates has been used to treat a variety of other metabolic diseases such as malignancy-induced hypercalcemia, tumor-induced osteolysis, and Paget’s disease (Iqbal, 2000).

**Selective estrogen receptor modulators.** Another class of pharmaceutical drugs used in the prevention and treatment of osteoporosis is selective estrogen receptor modulators, also commonly referred to as its abbreviated from SERMs (Iqbal, 2000). SERM drugs have been observed to be beneficial in diseases dependent on hormonal activity such as cardiovascular disease, endometrial and breast cancer, and osteoporosis, and function by reducing osteoclastic activity by increasing the use of pre-existing estrogen in the body (Iqbal, 2000; Byrd-Bredbenner et al., 2013). The first FDA approved SERM drug for the prevention of osteoporosis was Raloxifene. Raloxifene, a non-steroidal benzothiophene is effectively used in prevention of osteoporosis in postmenopausal women. The function of Raloxifene is facilitated through binding to estrogen receptors resulting in expression of various estrogen regulated genes through numerous tissues. Results of Raloxifene is known to increase total body, spine and total
hip bone mineral density although results are seen to a lesser extent as compared to estrogen replacement therapy (Iqbal, 2000).

**Calcitonin.** Similar to its natural form produced by the cells of the thyroid gland, pharmaceutical calcitonin functions in the manner by inhibiting osteoclast bone cells, and the bone resorption process (Gropper, & Smith, 2013; Byrd-Bredbenner et al., 2013). Administration of this peptide hormone is available in forms of a nasal spray, or as an injection (Iqbal, 2000; Riggs, & Melton, 1992). Oral forms of the medication are not offered due to the protein structure of calcitonin which was would digest readily without medication action allowed time to function. Injected forms of calcitonin are associated with adverse symptoms of nausea, vomiting, diarrhea, anorexia, facial flushing, tingling, rash, swelling of the lower extremities, and pain of the site of injection. Whereas the intranasal form however, is associated less severe side effects such as rhinorrhea, nasal dryness, crust, irritation, inflammation of the sinuses, nose bleeds, and headaches. In 1995, the FDA approved Miacalcin, an intranasal formula of salmon calcitonin, the most potent form of calcitonin for the treatment of osteoporosis. Although only small quantities of bone mineral density have been reported to have been gained or preserved in the vertebrae, the use of calcitonin may be a good alternative therapy method for perimenopausal women who cannot use estrogen therapy methods. In addition, its analgesic effect also aids to reduce pain associated with skeletal fractures (Iqbal, 2000).

**Parathyroid hormone.** Similar to the action of the parathyroid hormone in the body, pharmaceutical parathyroid hormone functions to accelerate osteoblastic and new
bone formation activity (Byrd-Bredbenner et al., 2013). This FDA approved agent is considered an anabolic form of therapy functions by accelerating bone formation, and activating the bone remodeling process (Rosen, Drezner, & Mulder, 2015; Banu, Varela, & Fernandes 2012). Administration of the parathyroid hormone agent is through injections given daily underneath the skin. Adverse effects of the use of the parathyroid hormone include injection site reactions, non-severe headaches, nausea, arthralgia, and in some cases hypercalciuria which was uncommon. In previous studies the use of the parathyroid hormone is associated with decrease in fractures of the vertebrae, increased vertebral bone density, and reduced symptoms of vertebral pain (Crandall, 2002). In addition, clinical cases in the U.S. and Europe, parathyroid hormone 1-34, better known as teriparatide or Forteo is used to treat patients with severe cases of osteoporosis and has been effectively observed to reduce the risk of non-vertebral fractures (Rosen et al., 2015). However, adverse effects such as a reduction in bone density of the radius has been observed with the use of the parathyroid hormone, and long term safety of the use of the drug is unknown (Crandall, 2002). Therefore, the use of the parathyroid hormone should be restricted to a maximum of a two year time period (Banu et al., 2012).

**Alternative therapies.** As discussed in the section of modifiable risk factors, calcium is known to play a vital role in overall bone health, therefore it should be no surprise that calcium supplementation is a preventative measure of osteoporosis. Similar to hormone replacement therapy, bisphosphonates, and calcitonin, calcium is considered an antiresorptive agent (Riggs, & Melton, 1992). Recommendations are 1,500 mg of calcium per a day for postmenopausal women and 1,000 mg for pre-menopausal women.
Although the benefit of calcium is not seen to slow down the accelerated bone loss that occurs during early menopause, beneficial effects are seen to increase bone density in premenopausal women with sufficient calcium intake. In addition previous studies on the geriatric population have indicated calcium supplement may prevent fractures of the hip and spine (Drake et al., 2008).

As discussed in the section of modifiable risk factors: vitamin D, vitamin D is known to play an important role in an individual’s health and bone status. Supplementation of vitamin D is not uncommon especially when sun exposure is limited due to the fact that food alone may not provide adequate vitamin D intake (Cleveland Clinic, 2010b). This form of alternative therapy may be principally useful in elderly individuals. Optimal vitamin D status is currently controversial; doses between 400-800 International Units (IU) are recommended (Iqbal, 2000). In general, a serum level of 30 ng/mL of 25-hydroxyvitamin D is indicative of an adequate vitamin D status (Drake et al., 2008).

Polyunsaturated omega-3 fatty acids, specifically docosahexaenoic acid and eicosapentaenoic acid may also have beneficial effects in bone metabolism through the regulation of osteoclastogenesis, prostaglandins, proinflammatory cytokines, and increasing calcium absorption in the gut. In addition, the effects of omega-3 fatty acids have been shown to be effective in improving bone constraints in male animal and human models. Dietary sources of fatty acids that have been deemed to provide a positive effect
on bone health include perilla oil, krill oil, flaxseed oil, salmon oil, cod liver oil, hemp oil and milk.

In addition, herbal remedies which have been used for centuries may also be beneficial bone protective properties. The ethanolic extract from allium cepa, or commonly known as the onion is known to provide bone protective properties by decreasing bone resorption, increasing bone mineral content, contribute to trabecular thickness, and bone mineral density. The extract of carthamus tinctorius, better known as safflower seeds are known to stimulate differentiation of osteoblasts, while methanolic extracts of carthamus tinctorius protects trabecular bone and increases insulin growth factors, and bone alkaline phosphatase in rodent trails while providing the bone forming benefit of safflower itself. Leaves used in green tea from the camellia sinensis plant also have been shown to increase bone formation while decreasing bone resorption n rodent models. Phytoestrogens, such as isoflavones also provide a benefit to bone by its estrogen like activity which helps to maintain bone while having few documented adverse effects. Dried plums, also referred to as prunus cultivar, or prunes have been observed to reverse bone loss among postmenopausal women, as well as decrease osteoclastic activity in a rat model. In addition, black cumin, black cohosh, veldt grape winged tree vine, ginger, and turmeric have been shown to have promising results in terms of bone health in rodent models (Banu et al., 2012).
Non-Modifiable Risk Factors

Osteoporosis is a multifactorial disease and, there are many risk factors that could predispose an individual to the disease (Marini, & Brandi, 2010). Two categories of risk factors are recognized. The first category is referred to as non-modifiable risk factors which encompass factors such as age, gender, ethnicity, bone structure, family history and history of fractures (Kohl, & Murray, 2012; Cleveland Clinic, 2012).

Advanced age is a major risk factor for osteoporosis (Orwoll, Bilezikian, Vanderschueren, 2010). Although a majority of the variable risk of osteoporosis is attributed to achievement of PBM, approximately 40% of the remaining variable risk is attributed to by bone loss which occurs at a faster rate due to the higher bone turnover that accompanies the aging process (Langman, & Trippe, 2010; Byrd-Bredbenner et al., 2013). Consequently, the risk of osteoporotic fractures increases exponentially with the aging process across both genders (Orwoll et al., 2010).

Gender is another major risk factor for osteoporosis. In the U.S. 80% of individuals who are affected by osteoporosis are women (Gropper, & Smith, 2013). Especially postmenopausal women or women over the age of 50, have the highest risk of developing the disease (Cleveland Clinic, 2012). In general, males tend to gain an average of 10-15% more PBM as compared to women (Lee, & Nieman, 2013). In addition, females tend incur more bone loss throughout their lives as compared to their male counterparts (Riggs, & Melton, 1992). This imbalance of bone loss between the genders is further progressed with accelerated bone loss which is observed in the first ten
years of menopause in women (Cleveland Clinic, 2012). Consequently, osteoporotic fractures are also more prevalent among the female population. Approximately one in every two women over the age of 50 will incur an osteoporotic fracture. On the other hand, only approximately one in every four males over the age of 50 incur a osteoporotic fracture in their lifetime, and only 30% of hip fractures worldwide are attributed to men (Gropper, & Smith, 2013; Colon-Emeric, & Saag, 2006). Although males have a lower risk of developing osteoporosis, a bone mineral loss of 20-30% is incurred throughout their lifetime, and an incidence of fracture is known to be greater associated with mortality in men as compared to women (Colon-Emeric, & Saag, 2006; Lee, & Nieman, 2013).

Ethnic differences are related to bone mass in terms of an individual’s risk for developing osteoporosis (Iqbal, 2000). African Americas are known to have the highest bone mineral density at every age, followed by individuals of Hispanic descent (Barrett-Conner et al., 2005). The higher bone mineral density in individuals of these ethnicities can be explained by a higher PBM that is attained (Iqbal, 2000). In general, African American individuals are known to have 10% greater bone density as compared to their Caucasian counterparts (Lee, & Nieman, 2013). On the contrary, Caucasians and Asian individuals have the greatest risk for developing osteoporosis with individuals of Asian descent having the highest risk due to low bone mineral density observed at every age (Iqbal, 2000; Barrett-Conner et al., 2005). However, observations related to the risk of fracture have been relatively low for individuals of the African American descent and
Asian descent. This discrepancy may be attributed to other musculoskeletal factors aside from bone mineral density (Barrett-Conner et al., 2005).

Differences between body frames have also been known to correlate with the risk for developing osteoporosis. A thin body frame has been associated with a greater risk of osteoporosis, while a heavier body frame seems to provide protection against developing the disease (Kamel, 2006). It has been observed that women who are obese tend to have a lower risk of developing osteoporotic fractures due to stimulation of osteoblast activity in response mechanical stress and greater estrogen production in increased fat tissues which supports bone maintenance (Wardlaw, 1996). A Body Mass Index (BMI) of 30, which is a considered in the obese spectrum in terms of BMI, has been linked with increased bone mineral density at the lumbar spine, hip, and radius, prominent locations of osteoporotic fractures. On the other hand, a BMI of 20, which is considered on the lower end of the healthy weight spectrum is linked with lower bone mineral density along the lumbar spine, hip, and radius and is associated with approximately twice as much bone loss in the lumbar spine bone mineral density in the early postmenopausal period (Byrd-Bredbenner et al., 2013; Wardlaw, 1996). In general, a BMI less than 24 is thought to be linked to lower bone mineral density as compared to a BMI greater than 26 (Wardlaw, 1996).

Two forms of skeletal changes that accompany menopause in women causes menopause to be a significant risk factor for osteoporosis. During this life stage estrogen deficiency causes an increase in bone turnover, which subsequently decreases total body
mineral matter, and trabecular bone mineral content by more than 7% and 20%, respectively. This negative imbalance between mineral and bone matrix ultimately decreases the amount of bone mass per each remodeling cycle, and accelerates bone loss during this period (Kanis, 1996). A previous study in the 1990’s conducted on Caucasian women in the U.S. ages 50 and above found that 32% of the target population had a BMD lower than 2 standard deviations at the site of the lumbar spine, whereas 31% had low bone mineral content at the skeletal site of the distal radius (World Health Organization Study Group, 1994). Another study conducted on postmenopausal women who were monitored for a mean of 15 years concluded a decreased in bone mineral density of approximately 1.9%, and a decreases in bone strength of approximately 0.7% yearly (Ahlborg, Johnell, Turner, Rannevik, & Karlsson, 2003). Menopause in women can occur through natural or surgical means. Natural menopause, as discussed earlier, occurs in a slow and steady and noninvasive fashion where ovarian function decreases over a period of several years until cessation of the menses cycle occurs (Ozdemir et al., 2009). Surgical menopause on the other hand is an invasive procedure that surgically removes the ovaries (Cleveland Clinic, 2010b). This surgical procedure is known as a bilateral oophorectomy and is characterized by the sudden decrease in estrogen, progesterone, and androgens (Cleveland Clinic, 2010b; Ozdemir et al., 2009). Women who undergo surgical menopause are known to have a significantly higher risk for osteoporosis and lower bone mineral density as compared to women who undergo natural menopause. A previous study revealed that women who have undergone an oophorectomy had approximately twice the rate of bone loss in less than a decade after
the surgery (Ozdemir et al., 2009). In addition, a 3% bone loss per a year has been observed in post-oophorectomy patient within a three year time period (Riggs, & Melton, 1992).

Due to the genetic contribution in bone, family history is a major risk factor of osteoporosis. Approximately 70% of osteoporosis cases are the effect of genetic predisposition, while the remaining 30% are attributed to environmental factors (Iqbal, 2000). Data suggests a strong relationship between family history and osteoporotic fractures in women, with a maternal history of a hip fracture being a significant factor. A previous study conducted on approximately 10,000 Caucasian females found women who had a maternal family history of a hip fracture before the age of 80 were twice as likely to have a hip fracture them self as compared to other women who did not have a maternal family history of a hip fracture (Cummings et al., 1995). However, in men this relationship does not seem to exist to the extent that it does in females (Orwoll et al., 2010). However, a study by Looker, and Beck (2004) revealed that both genders with a maternal FHO were more likely to sustain a femur neck fracture, and differences were observed among ages as compared to genders. In addition, a large cohort study conducted by Diaz, O’ Neill, and Silman (1997) found a positive correlation between maternal history of hip fracture and vertebral deformity in men.

Personal history of fracture after the age of 40 is also considered a significant indicator for subsequent osteoporotic fractures. An increase in subsequent fractures especially along the hip, vertebrae, and distal radius has been observed. An initial
vertebral column fracture is known to increase a second fracture along the vertebrae and non-vertebrae fracture by a minimum of fourfold. The risk for following fractures among individuals with a past medical history of a fracture at any site is 2.2 times that of individuals of same age and gender (Orwoll et al., 2010).

**Modifiable Risk Factors**

Modifiable risk factors, on the other hand include low physical activity, low calcium intake or absorption, low vitamin D intake or absorption, low levels of estrogen or testosterone, certain medications such as steroids, tobacco use, alcohol abuse, and excessive caffeine, sodium and protein intake (Kohl, & Murray, 2012; Cleveland Clinic, 2012; Gropper, & Smith, 2013).

**Calcium Intake**

Calcium is the most abundant mineral in the body comprising approximately 40% of the body’s mineral mass, and making up approximately 2% of the body’s total weight. Approximately 99% of calcium is found within the bones and teeth providing them with their structural component and strength (Gropper, & Smith, 2013; Flynn, 2003). The remaining 1% is found within the intracellular and extracellular fluids of the body with extreme differences between concentrations (Gropper, & Smith, 2013; Khanal, & Nemere, 2008). Calcium found intracellularly is maintained around 0.1 micrometer, and is an essential second messenger and cofactor for enzymes and proteins which regulate processes of neurotransmission, motility, hormonal secretion and cellular proliferation. On the contrary, calcium extracellularly is maintained around one micrometer and is a
fundamental fragment of the mineral phase of bone which serves as a cofactor for adhesion molecules, blood clotting, and other proteins. Neuronal excitability is also regulated by extracellular calcium (Khanal, & Nemere, 2008).

**Importance of calcium in bone health.** In regards to bone health calcium is a major constituent of bone and plays a crucial structural role as a component of hydroxyapatite, which predominantly composes the inorganic component of bone and provides the skeleton entity with strength and rigidity (Flynn, 2003; Henrikson et al., 1997; Bauer, 2013). Bone also acts as a metabolic calcium reservoir allowing calcium to be stored and released when it is needed for the maintenance of extracellular fluid (Bauer, 2013; Flynn, 2003). The attainment of PBM is done in predominantly accomplished in early life stages, and is a major determinant of bone mass later in life, and subsequently important in preventing osteoporosis (Heaney et al., 2000; Valimaki et al., 1994). A previous study conducted by Wang et al. (2003) found that calcium intake above 1000 mg/day during midpuberty was positively correlated with higher bone mass during the young adult life stage. Similarly, another study by Matkovic et al. (2007) found calcium supplementation of a total of approximately 1500 mg of calcium per a day during puberty was positively associated with bone deposition among young female participants.

In regards to osteoporosis calcium is known to have a positive beneficial effect on bone mineral density (Angelo, 2012). Previous studies have shown increasing calcium intake in the premenopausal and postmenopausal period allows women to enter menopause with a higher bone mineral density and may decrease bone loss by up to 50%
at non-vertebral sites (Riggs, & Melton, 1992; Iqbal, 2000). Previous studies have also shown that calcium intakes under 700-800 mg/day are associated with increased bone loss and risk of fracture (Bauer, 2013). In addition, calcium has also been recognized to enhance PBM which contributes to 60% of the variable risk in developing osteoporosis (Iqbal, 2000; Langman, & Trippe, 2010).

**Hormonal regulation of calcium homeostasis.** Calcium may be transferred to cells by being bound to proteins or as free ionized calcium and is a crucial component in all cells (Gropper, & Smith, 2013). Due to its major role in the body even a minor fluctuation of extracellular calcium concentration can cause detrimental effects such as severe neuromuscular, neurologic, or renal complications which can lead to death (Gropper, & Smith, 2013; Downey, Myers, Gonzalez, & Lieberman, 1994). For example, a major imbalance in calcium concentrations known as hypercalcemia can lead to cardiac failure in individuals, whereas hypocalcaemia can have a fatal outcome due to muscular convulsions that it may cause (Edwards, 2005). Therefore, calcium present in the bloodstream is tightly controlled between 8.5-10.5 mg/dL by hormonal regulation by the parathyroid hormone, calcitonin, and calcitriol for normal physiological functioning (Byrd-Bredbenner et al., 2013; Gropper, & Smith, 2013; Angelo, 2012).

The action of the parathyroid hormone, an 84 amino acid long polypeptide results in a net increase of calcium concentration in the blood (Gropper, & Smith, 2013; Rosen et al., 2015). The chief cells of the parathyroid gland are known to be responsible for the secretion of the parathyroid hormone when the extracellular concentration of calcium
drop below 8.5 mg/dL (Gropper, & Smith, 2013). This reduction in extracellular calcium concentration is inversely related to serum albumin concentrations, therefore the higher the concentration of serum albumin, the lower the extracellular concentration of ionized calcium will be (Miller, & Graham, 2006). The detection of low calcium concentration in the blood is accomplished by the action of calcium-sensing receptors found on the parathyroid gland and kidney tubular cells. Increase of calcium concentrations in the plasma are achieved by interactions with the kidney and bone. In the kidney, the parathyroid hormone activates vitamin D thus increasing the synthesis of calbindin D28k, a small, globular, stable calcium binding protein, subsequently increasing renal tubular calcium reabsorption and decreasing calcium excretion (Gropper, & Smith, 2013; Byrd-Bredbenner et al., 2013; Linse et al., 1991). In the bone, the parathyroid hormone increases calcium mobilization by stimulating osteoblast activity producing macrophage colony stimulating factor and receptor activator of nuclear factor K B ligand known as RANKL The action of these proteins ultimately stimulates osteoclasts by binding to RANK receptors on osteoclast precursor cells, and increase resorption of bone, which in turn increases extracellular calcium concentrations by releasing calcium from the bone to the plasma (Gropper, & Smith, 2013).

The most active form of vitamin D is known as calcitriol (1-25-(OH)2 vitamin D) (Byrd-Bredbenner et al., 2013; Gropper, & Smith, 2013). Calcitriol is produced in by the kidney and results in a net increase of calcium concentration to the normal range through interactions with the kidney, bone and intestines. In bone, calcitriol works with the parathyroid hormone to promote bone demineralization through resorption by
osteoclastic activity (Gropper, & Smith, 2013; Byrd-Bredbenner et al., 2013). In a large study on postmenopausal women results revealed that treatment of osteoporosis with calcitriol significant reduced vertebral fractures by threefold, as compared with treatment with calcium supplementation (Tilyard, Spears, & Thomson, 1992). Similar to the interactions of the parathyroid in the kidney, calcium and phosphorus excretion is decreased by calcitriol (Byrd-Bredbenner et al., 2013). In the gastrointestinal tract calcitriol serves as a chief determinant of calcium absorption (Tilyard et al., 1992). In the intestinal tract calcitriol increases calcium and phosphorus absorption in the intestines and aids calcium transport through cytosol of the enterocyte by stimulating transcription of the genes that are responsible for calbindin D9k (Byrd-Bredbenner et al., 2013; Gropper, & Smith, 2013). Calcitriol in the intestines also increases calcium ATPase pumps at the basolateral membrane and TRPV6 channels at the brush border to increase calcium absorption (Gropper, & Smith, 2013).

As compared to the parathyroid hormone and calcitriol, the action of calcitonin is in response to calcium concentrations above the normal threshold and results in a net decrease of calcium concentration in the blood (Gropper, & Smith, 2013). Calcitonin is synthesized in the parafollicular cells of the thyroid gland and acts on the bone, kidney and gastrointestinal tract by suppressing the production and release of the parathyroid hormone, and inhibiting osteoclast activity and bone resorption (Gropper, & Smith, 2013; Byrd-Bredbenner et al., 2013).
Calcium Absorption

In order to understand calcium absorption and its efficacy it is important to note that it is dependent on calcium transport in the small intestine, as well as a variety of factors including but not limited to physiological statuses such as life stages, pregnancy, and lactation (Allen, 1982).

Calcium Transport in the Small Intestine

There are two main calcium processes that are noted. The first and main method of transport is under hormonal control, saturable, active and has a transcellular transport pathway (Khanal, & Nemere, 2008; Stipanuk, 2006; Gropper, & Smith, 2013). This method of transport accounts for approximately 60% of the total calcium absorption in meals that contains 400-500 mg of calcium and is predominately found in sites of the small intestine including the duodenum and proximal jejunum (Stipanuk, 2006; Gropper, & Smith, 2013). The acidic pH in the upper portion of the small intestine allows calcium to dissolve into its ionic form (Byrd-Bredbenner et al., 2013). This transcellular process is regulated by 1,25 dihydroxy-vitamin D and involves the calcium binding protein known as calbindin D, the basolateral calcium ATPase, and the TRPV6/Calcium transporter 1, the vitamin D dependent membrane channel protein and is energy dependent (Stipanuk, 2006; Gropper, & Smith, 2013).

The second method of transport is dependent on the concentration, and typically occurs when calcium concentrations in the lumen are high (Gropper, & Smith, 2013). This method of transport is nonsaturable in nature, and has a paracellular mode of
transport (Stipanuk, 2006). This paracellular method of transport though passive diffusion is independent of 1,25 dihydroxy-vitamin D, protein carriers, or energy and exists throughout the entirety of the intestine, but is mostly active in the jejunum and ileum where intestinal matter becomes more alkaline (Stipanuk, 2006; Khanal, & Nemere, 2008; Gropper, & Smith, 2013; Byrd-Bredbenner et al., 2013).

**Factors affecting Calcium Absorption**

Typically calcium absorption among adults ranges from 25-30% through the means of the diet, and 27-39% from calcium supplements depending on factors of the type of supplement, amount of calcium in the supplement, and if it was taken with or without food. In children and infants calcium absorption is approximately 60% from calcium sources in the diet, and decreases to approximately 15-20% with aging and estrogen loss in females. Calcium absorption is variable and may be inhibited or enriched by various factors (Gropper, & Smith, 2013).

Factors that increase calcium absorption include vitamin D, increased needs which are observed in stages of growth, childhood, pregnancy, and lactation, and diets low in calcium (Gropper, & Smith, 2013). Protein, sugars, and sugar alcohols also increase calcium absorption when paired with calcium rich foods (Byrd-Bredbenner et al., 2013). In addition lactose is also known to enhance the effectiveness of calcium diffusion, and is known to be more beneficial in infants as compared to adults (Gropper, & Smith, 2013).
Factors that decrease calcium absorption include high calcium intake, use of proton pump inhibitors, decreased secretion of stomach acid, unabsorbed fatty acids which ultimately can form unabsorbable soaps in the intestinal lumen, and chronic diarrhea (Gropper, & Smith, 2013; Byrd-Bredbenner et al., 2013). Oxalic acid which is also referred to as oxalate also decreases calcium absorption by chelating calcium in the ionized form. It has a very low solubility and is known to increase calcium excretion through fecal matter. Oxalate is typically found in vegetables such as spinach, fruits such as blackberries and strawberries, nuts, and beverages such as tea and cocoa. Phytic acid also referred to as phytate or inositol hexaphosphate, found in legumes seeds, and in whole grain breads, and fiber also decrease calcium absorption through a mechanism of binding to calcium and subsequently decreasing its availability (Gropper, & Smith, 2013). A previous study found that meals that contain as little as 100 mg of phytate can reduce calcium retention by 30% (Fredlund, Isaksson, Rossander-Hulthen, Almgren, & Sandberg, 2006). It is important to note that calcium absorption also decreases with age and typically in the postmenopausal phase as well (Byrd-Bredbenner et al., 2013). The expression of key players in the first method of transport, TRPV6 and calbindin, are known to decline as one ages. This decline in expression partially accounts for increased calcium needs of individuals in the geriatric population (Gropper, & Smith, 2013).
Food Sources of Calcium

Calcium is an essential mineral which means that the body does not synthesize calcium but it must be provided through the means of the diet. Dietary sources of calcium include dairy, non-dairy, and fortified items (Weaver, Proulx, & Heaney, 1999).

Dairy sources of calcium. The best sources of calcium are from highly consumed milk and dairy products such as yogurt, and cheese. In the U.S. dairy products compose 75% of calcium in the American diet (Weaver et al., 1999). A recent study revealed that American adults consumed approximately 0.69 servings of milk per a day, ranking the 64th out 187 countries in highest milk consumption (Tufts University Health Sciences Campus, 2015). The gold standard for calcium is milk containing approximately 300 mg of calcium per a cup (Byrd-Bredbenner et al., 2013). An 18-year analysis study conducted by Feskanich, Willett, and Colditz (2003) found that milk provided 36% of dietary calcium, as well as 42% of dietary vitamin D among 72,337 postmenopausal women. Unfortunately, in the U.S. a decrease in milk consumption in children and adolescents has been observed (Cavadini, Siega-Riz, & Popkin, 2000).

Yogurt, on the other hand can differ in calcium content depending on type and/or brand. For example fat free plain yogurt contains approximately 488 mg per an eight oz. cup; whereas a fat free fruit yogurt only contains approximately 372 mg/ eight oz. cup (Dairy Council of California, 2015). Cheese also differs based upon the type of cheese. For instance, Swiss cheese contains 224 mg of calcium per an ounce (oz.), the highest among five widely consumed cheeses, while parmesan contains only 55 mg per a tablespoon.
(Dairy Council of California, 2015). However, it should be noted that not all dairy products are considered a good source of calcium. Cottage cheese for example is not considered a good source of calcium due to the processing method which makes calcium loses inevitable. Other dairy products such as butter and cream cheese are also not considered good sources of calcium due to their nutritional composition which mainly contains a high amount of fat (Grodner, & Escott-Stump, 2016). Dairy products provide a high bioavailable form of calcium into the diet with an absorption rate of approximately 30 percent (Byrd-Bredbenner et al., 2013).

**Non-dairy sources of calcium.** Non-dairy products such as salmon or sardine with bones, clams, oysters, leafy green vegetables such as spinach and kale, nuts and legumes also provide a good source of calcium into the diet, although the rate that they are absorbed may be lower (Gropper, & Smith, 2013; Byrd-Bredbenner et al., 2013). For example, a ½ cup of cooked rhubarb provides 175 mg of calcium, but only has a 5% bioavailability, yielding only nine mg of calcium for absorption (Byrd-Bredbenner et al., 2013; Stipanuk, 2006). Non-dairy users and vegans alike should caution calcium bioavailability in order to ensure they are getting adequate calcium in their diets (Byrd-Bredbenner et al., 2013).

**Fortified food sources of calcium.** Fortified foods such as orange juice, breakfast cereals, crackers, soy milk, rice milk, and certain breads also are good sources of calcium (Gropper, & Smith, 2013; Byrd-Bredbenner et al., 2013). For example, fortified orange juice provides approximately 350 mg of calcium per day providing
nearly 35% of the Recommended Daily Allowance (RDA) for adults (Gropper, & Smith, 2013). Although it should be noted that calcium fortified beverages such as fortified orange juice and fortified soy beverages is not an equivalent to milk (Straub, 2007; Heaney, Rafferty, & Bierman, 2005). A study conducted by Heaney et al. (2005) revealed that all calcium fortified beverages do not have the same bioavailability due to absorbability characteristics found in the fortification systems, which are varied among brands. This study also revealed calcium absorption of a soy beverage was 25% less than that of milk. However in practical application calcium fortified products do provide a convenient option for children or individuals who have difficulty swallowing supplement tablets, vegans, and individuals who have dairy intolerances or allergies (Straub, 2007).

**Calcium Supplements**

Although calcium is recommended to be consumed through means of the diet, calcium supplementation should be considered when dietary intake is insufficient (Bauer, 2013). A previous meta-analysis revealed that calcium supplementation did in fact have a positive effect on BMD, and a non-significant trend toward decreased fractures of the vertebrae were observed in postmenopausal women (Shea et al., 2002). In the U.S. the use of calcium supplementation has increased 4.8% from 1992 to 2000, and currently approximately 45% of Americans report using calcium supplements. While calcium supplements have been found to have beneficial effects in regards to bone health in children, young adults and menopausal women the use of calcium supplements should be managed with care in order to prevent against prostate cancer, hypercalcemia, and
decreased absorption of other micronutrients such as zinc, iron, and magnesium (Straub, 2007; Byrd-Bredbenner et al., 2013). Lead contamination in calcium supplements is also a serious concern, and is known to cause permanent fetal brain damage, high blood pressure, heart disease, kidney impairment, compromised bone synthesis, decreased sperm production, and osteoporosis at low levels of exposure (Scelfo, & Flegal, 2000). In a previous study approximately 25% of calcium supplements were found to be contaminated by lead, with a greater risk of contamination among supplements made from natural sources such as bonemeal, dolomite, or oyster shell (Byrd-Bredbenner et al., 2013; Scelfo, & Flegal, 2000). In another study conducted on 136 brands of calcium supplements purchased in 1996 revealed two-thirds of the supplements analyzed were considered to contain appropriate levels of lead as deemed by California criteria in 1999 (Scelfo, & Flegal, 2000).

Calcium supplements are available over the counter and come in many forms such as tablets, capsules, chews, powders, wafers, and liquids (Bauer, 2013; Straub, 2007). Various types of calcium supplements exist on the market including calcium citrate, calcium carbonate, calcium gluconate, calcium lactate, bone meal, oyster shell, dolomite, and coral calcium (Byrd-Bredbenner et al., 2013; Bauer, 2013). These supplements mainly differ in the manner in they are prepared based on quantity of elemental calcium contained in the supplement (Bauer, 2013). It is important to note that calcium supplements should contain less than 500 mg of elemental calcium per a dose due to decreased calcium absorption with higher intake and should be taken with caution under the guidance of a medical professional due to multiple drug-nutrient interactions.
with drugs such as corticosteroids, and thiazide diuretics and food-nutrient interactions with fiber, iron, zinc, magnesium, caffeine, and sodium (Straub, 2007; Dairy Research Institute, 2011).

Calcium citrate and calcium carbonate are the two most widely available calcium supplements in today’s market and is thought to have calcium absorption similar to that of milk. Calcium citrate is thought to be beneficial to a higher degree when used by the geriatric population. This is due its ability to be used with long-term gastric acid suppressants, limited dependency on gastric acidity for absorption, and consequently its ability to be consumed with or without food. A study on postmenopausal women conducted by Kenny et al. (2004) determined that calcium citrate supplementation was significantly more effective in decreasing markers of bone as compared to calcium carbonate supplementation. Calcium citrate contains approximately 21% of calcium by weight, and dosing typical varies between one to two 950-1000 mg tablets taken two to three times a day (Gropper, & Smith, 2013; Bauer, 2013). A popular brand of calcium citrate is Citracal (Heaney, 1991).

Calcium carbonate on the other hand, is the single most widely used and most inexpensive calcium supplement on the market, costing consumers approximately a third of the cost of the least expensive food source (Bauer, 2013; Straub, 2007). Brands of calcium carbonate supplements include but are not limited to Caltrate, Biocal, Tums, Tums E-X, and Os-Cal 500 chewable (Heaney, 1991). Calcium carbonate supplements have the highest proportion of calcium in supplements containing approximately 40%
elemental calcium content (Bauer, 2013; Byrd-Bredbenner et al., 2013). Doses of one to two 500 mg tablets taken two to three times daily are typically required (Bauer, 2013). As compared to calcium citrate this form of calcium supplement should be taken with meals due to the fact that gastric acidity is required for adequate absorption in the body, and should not be used by individuals using medications to treat gastroesophageal reflux (Bauer, 2013; Straub, 2007). Caution should also be advised when using calcium carbonate as it is known to have side effects of constipation, bloating, and gas (Gropper, & Smith, 2013).

Calcium gluconate, calcium lactate, bone meal, oyster shell, dolomite, and coral calcium are used to a lesser extent in terms of calcium supplements. Calcium gluconate contains approximately 9% calcium by weight and is usually found in doses of 500 mg, 648 mg or 972 mg. Calcium lactate contains approximately 13% of calcium by weight and is usually found in doses of 300 mg or 325 mg. Both of these products are rarely used in the for the purpose of preventing fractures or in the clinical setting due to the small concentration of calcium that they yield (Bauer, 2013; Straub, 2007).

Bone meal, oyster shell, dolomite, and coral calcium are predominately made of calcium carbonate, and contain approximately 30% calcium by weight (Bauer, 2013; Straub, 2007). These supplements have been linked with lead and/or aluminum contamination, and should be avoided in general but especially by pregnant women (Bauer, 2013; Byrd-Bredbenner et al., 2013; Straub, 2007). In the 1980’s in addition to lead contamination bone meal was also found to be contaminated with arsenic, mercury,
and cadmium (Straub, 2007). To lessen the risk of ingesting supplements that have been contaminated, only brands that have been approved by the U.S. Pharmacopeia (USP) should be purchased (Byrd-Bredbenner et al., 2013; Straub, 2007). The USP is a nongovernment, nonprofit organization that was formed to set standards for health products such as prescription drugs, over the counter medications, and dietary supplements. Although supplement manufactures do not have to follow USP standards, voluntary verification to this process provides consumers assurance of the quality of the dietary supplement they are purchasing (Straub, 2007).

**Calcium Recommendations**

Dietary requirements for calcium vary throughout various life stages, and are determined by the needs of the bones in terms of development, and maintenance (Flynn, 2003). The RDA for calcium in adults is 1,000 mg/day (Gropper, & Smith, 2013). Life stages such as childhood, adolescence, menopause, and elderly states require increased calcium needs (Flynn, 2003). In children and adolescents across both genders 1,000 mg/day, and 1300 mg/day of calcium is recommended. In females by the age of 51 calcium recommendations spike to 1,200 mg/day which is also required by males by the time they are 70 years old (Gropper, & Smith, 2013).

However, most Americans do not consume adequate amounts of calcium that is recommended. Approximately one-fourth of adult women only consume approximately 600 mg of calcium per day, and approximately a half of adolescent females consume less than 65% of the RDA. This issue is seen to a lesser extent in adult males under the age of
51, but is seen in increase dramatically in men over the age of 70 with more than 80% of individuals in this population not reaching recommendations (Byrd-Bredbenner et al., 2013). It is important to note that physiological processes of calcium may be affected over an extended period of calcium inadequacy paired with daily losses of calcium through urine, stool, and sweat (Bauer, 2013).

Although large doses of calcium are recommended for every life stage and calcium sources in foods and supplements are not known to pose a serious health threat, especially due to inadequate intake among the general population the upper limit (UL) of calcium should be made note of. The UL for calcium is 2,500 mg/day for adults’ ages 19-50 and 2,000 mg/day for adults over the age of fifty. Excessive intakes of calcium can cause irritability, headaches, decreased absorption of other micronutrients, and increases the risk of developing kidney stones, kidney failure and hypercalcemia, a serious condition characterized by an elevated concentration of calcium in the bloodstream which may cause loss of appetite, anorexia, nausea, vomiting, bone mineralization, weakness, joint pain, kidney stones, hypertension, calcium deposits in organs, and kidney failure (Byrd-Bredbenner et al., 2013).

Vitamin D

Vitamin D is a fat-soluble vitamin derived from cholesterol with three structurally intact rings (Byrd-Bredbenner et al., 2013; Gropper, & Smith, 2013). The function of vitamin D throughout the body is vast serving as a mediator for multiple metabolic functions, and regulating neuromuscular activity. Two different forms of the vitamin D
exist including vitamin D2, and vitamin D3 which is also referred to as ergocalciferol and cholecalciferol respectively. Ergocalciferol, is normally found naturally in dietary sources, or is added into foods while cholecalciferol is the form of vitamin D that is synthesized by the skin (Holick, 2005).

**Hydroxylation process.** Dietary absorption of ergocalciferol and cholecalciferol are absorbed from micelle cells with lipids and bile salts which aid its absorption into intestinal cells by passive diffusion (Gropper, & Smith, 2013). Once vitamin D enters the body it may transport to muscle or adipose tissue for storage, or will undergo hydroxylation (Byrd-Bredbenner et al., 2013). Both forms of vitamin D, ergocalciferol and cholecalciferol are required to undergo 2 types of hydroxylation processes (Holick, 2005). The first hydroxylation process occurs in the liver on carbon 25 converting vitamin D2 or D3 to 25-hydroxyvitamin D3 which is known as the inactive storage form of vitamin D (Holick, 2005; Byrd-Bredbenner et al., 2013). This form of vitamin D then travels to the kidney in response to elevated concentrations of the parathyroid hormone for a second hydroxylation process on carbon one to form 1α,25-dihydroxyvitamin D3 commonly referred to as calcitriol (Holick, 2005; Byrd-Bredbenner et al., 2013; Gropper, & Smith, 2013). It is important to note that liver disease or kidney disease will impair the hydroxylation processes and therefore impair synthesis of 1α,25-dihydroxyvitamin D3 (Byrd-Bredbenner et al., 2013).

**Active form of vitamin D.** The most active form of vitamin D is calcitriol. This form of vitamin D has many significant regulating functions in the body including
maintenance of bone health by regulating calcium metabolism, absorption, reabsorption and deposition, in immunity, secretion of hormones such as insulin, renin, and parathyroid hormone, and possibly in the cell cycle (Byrd-Bredbenner et al., 2013; Gropper, & Smith, 2013). In addition, calcitriol is known to decrease certain types of infections, autoimmune diseases and have a protective benefit against chronic diseases such as diabetes, hypertension, cardiovascular disease, and certain types of cancers. Although much is known about vitamin D and its role, the need for intervention studies is still needed (Byrd-Bredbenner et al., 2013; Holick, 2004).

**Importance of vitamin D in bone health.** The most important contribution of vitamin D is known to be due its effects on bone health influencing strong bones, and skeletal growth by maintaining calcium and phosphorus concentrations in the presence of low calcium levels in the bloodstream (Gropper, & Smith, 2013; Byrd-Bredbenner et al., 2013; Angelo, 2012). In addition, calcitriol acts with the parathyroid hormone and is discussed more in the previous section of hormonal regulation of calcium homeostasis (Gropper, & Smith, 2013).

Vitamin D plays a critical role in promoting bone health, but it is important to note adverse effects that are associated with a vitamin D deficient status (Stipanuk, 2006). In general, in a vitamin D deficient state the gut will only absorb 10-15% or the dietary calcium, as compared to the normal state where intestinal absorption is approximately 30 percent (Holick, 2004). In children, deficiency in vitamin D is known to causing bones to weaken and bend, a condition referred to as rickets. Signs of rickets
include enlargement of head, joints and rib cage, pelvic deformities, and the classic sign, bowed legs. In adults, vitamin D deficiency is known to cause osteomalacia, a condition characterized by soft bones and newly synthesized calcium deprived bones which mostly affects aging individuals or individuals with malabsorptive, kidney, and liver diseases. Resulting signs of osteomalacia include fractures at the hip, spine, and other skeletal sites (Byrd-Bredbenner et al., 2013).

**Dietary sources of vitamin D.** For the reason that the body can synthesize vitamin D, it is not required to be consumed in the diet unless if adequate needs are not met (Byrd-Bredbenner et al., 2013). Both ergocalciferol and cholecalciferol are found in dietary sources, although cholecalciferol is known to provide a better source of vitamin D and is found in foods with an animal origin (Byrd-Bredbenner et al., 2013; Gropper, & Smith, 2013). Approximately 50% of dietary vitamin D is absorbed into the body. In addition, dietary sources of vitamin D are stable in form, and not susceptible to storage, cooking, or processing losses (Gropper, & Smith, 2013). The best dietary sources of vitamin D include fatty fish such as salmon, mackerel, herring, and sardines, providing 11, 1.7, 2.4, and 4.1 µg of vitamin D per every three oz., respectively (Byrd-Bredbenner et al., 2013; Gropper, & Smith, 2013). Cod liver oil, treated mushrooms, and fortified milk are also known to be considered good sources of vitamin D (Byrd-Bredbenner et al., 2013; Holick, 2004). Food sources such as cheesees, eggs, liver, butter, and some brand-names of margarine also contain vitamin D, but are not considered significant sources of the vitamin due to miniscule quantity found in these sources.
Foods that are fortified are typically fortified with ergocalciferol, and include milk, yogurt, cheese, butter, margarine (Byrd-Bredbenner et al., 2013; Gropper, & Smith, 2013). Some brands of orange juice, breads, and breakfast cereals may also be fortified with vitamin D (Gropper, & Smith, 2013). In the U.S. milk is typically fortified with vitamin D and can be found in the form of cholecalciferol providing 100 IU of vitamin D per a cup (Gropper, & Smith, 2013; Holick, 2004).

Vitamin D supplementation may also come in the form of vitamin D2, but mostly comes in the form of vitamin D3 (Byrd-Bredbenner et al., 2013; Gropper, & Smith, 2013). Although many studies have conveyed vitamin D supplementation in combination with calcium has shown to have beneficial effects as a preventive treatment against osteoporosis, caution should be advised when taking vitamin D supplementation as it is known to be one of the most probable prospective vitamins to cause toxicity (Tang, Eslick, Nowson, Smith, & Bensoussan, 2007; Gropper, & Smith, 2013).

**Vitamin D recommendations.** RDA for vitamin D did not exist prior to 2010 due to individual variability of sun exposure. With the help of experts from the Institute of Medicine he recommendation set in place assumed minimal sunlight exposure and took into account on average U.S. individuals need approximately 400 IU of vitamin D on a daily basis (Byrd-Bredbenner et al., 2013; Gropper, & Smith, 2013). For children over the age of one, adolescents, pregnant women, and lactating women the RDA was set at 600 IU. Older adults ages 70 and above the RDA for vitamin D was set at 800 IU (Gropper, & Smith, 2013).
**Vitamin D sun exposure.** Vitamin D is commonly referred to as the sunshine vitamin, due to the fact that approximately 90% of vitamin D requirements for the body are met by sun exposure (Holick, 2005; Holick, 2004). Generally, a serum 25(OH) D level greater than 30 ng/mL is considered to imply vitamin D sufficiency for maximal beneficial effects on health (Holick, & Chen, 2008). The mechanism of vitamin D synthesis on the skin begins with 7-dehydrocholesterol found in sebaceous glands throughout the skin. Upon sun exposure this compound undergoes a chemical change on the one ring of the molecule to form cholecalciferol which can enter the blood to be hydroxylated to its active form calcitriol (Byrd-Bredbenner et al., 2013; Gropper, & Smith, 2013).

**Factors that affect vitamin D intake from sun exposure.** The amount of vitamin D intake from sun exposure is dependent on multiple variables such as time of day, sunscreen usage, latitude, season, skin type, age, air pollution, glass in windows, and religious beliefs. The optimal time of day for sun exposure is from 10 A.M. to 3 P.M. for vitamin D synthesis (Gropper, & Smith, 2013). Due to increased awareness of photoaging of the skin and skin cancer in the society today, sunscreen usage poses as a determinant of vitamin D intake from sunlight (Stipanuk, 2006). Sunscreen functions by absorbing the UV light, and has been known to reduce some types of skin cancer and photoaging of the skin, although any sunscreen above SPF 8 is known to prevent sufficient vitamin D production (Stipanuk, 2006; Byrd-Bredbenner et al., 2013). Sunscreen with SPF 8 has been seen to reduce vitamin D synthesis by more than 95 percent (Holick, 2004).
Latitudes beyond 35 degrees are associated with decreased or no vitamin D synthesis especially in the winter season (Gropper, & Smith, 2013). For example individuals located at 42 degrees latitude in Boston, Massachusetts only have the capability to synthesis vitamin D from sun exposure from March through October, and do not produce any vitamin D through the months of November through February (Stipanuk, 2006; Byrd-Bredbenner et al., 2013). This is due to the fact that even though the sun is closer to earth in proximity in the winter seasons, the UV light that produce vitamin D are slanted as they pass through the ozone layer, and subsequently mostly absorbed by the ozone itself (Holick, 2004; Stipanuk, 2006). However, in young adults and children it should be noted that if vitamin D status is adequate during the spring, summer and fall seasons it will be sufficient during the winter season if fat tissue is available for storage (Stipanuk, 2006).

Skin type is also a major determinant of vitamin D intake from sunlight. The darker the pigmentation of the skin the lesser the production of vitamin D is in the skin and the longer the individual will have to be exposed to the sun (Stipanuk, 2006). For example, an adult with a type III skin will observed a 50 fold increase in vitamin D blood concentrations within an eight hour period after being exposed to one minimal erythemal dose of 54 mJ/cm². On the other hand, an adult with type V skin would not have any significant changes in vitamin D blood concentrations under the same circumstances (Holick, 2004). The underlying mechanism is due to melanin pigmentation which competes with 7-dehydrocholesterol on the skin for UV light similar to when one uses sun screen. On average, a pale individual will need to have to have approximately ten
fold less of duration of sun exposure as compared to their counterpart with very dark pigmented skin to produce sufficient vitamin D (Stipanuk, 2006).

Increased age is also seen to decrease an individual’s capability to synthesize vitamin D in the skin. This is due to diminishing concentration of 7-dehydrocholesterol in the skin as the aging process continues. By the time one is 70 years old, it is said that vitamin D production by the skin will decrease by approximately 75 percent. Making supplementation required for the elderly population, especially if the reside in extreme northern or southern latitudes (Stipanuk, 2006).

Religious beliefs among certain populations include covering most of their skin’s surface by clothing. This also can cause inadequate vitamin D intake from the sun due to the fact that clothing as well as air population, and glass windows will absorb most of the UV light (Stipanuk, 2006; Gropper, & Smith, 2013). This can ultimately lead to vitamin D deficiency. For instance, in the Negev Desert in Israel individuals with religious beliefs that include covering their bodies are known to be susceptible to vitamin D deficiency (Stipanuk, 2006).

**Vitamin D toxicity.** Vitamin D toxicity cannot occur due to excessive sun exposure or from the means of the diet, but can only occur from when ingested in large quantities from supplementation. The current upper tolerable limit for vitamin D is set at 1,000-3,000 for infants and children up to the age of 8 years old, and 4,000 IU for individuals ages nine and older (Byrd-Bredbenner et al., 2013; Gropper, & Smith, 2013). Toxicity of vitamin D result in a variety of conditions, signs and symptoms including
hyperphosphatemia, hypertension, anorexia, nausea, weakness, headaches, renal insufficiency, renal failure, and conditions of hypercalcemia and calcinosis, which is a condition characterized by the calcification of soft tissues of the organs and blood vessels (Gropper, & Smith, 2013). Death may also occur due to vitamin D toxicity if the condition is untreated over a prolong period of time (Byrd-Bredbenner et al., 2013).

**Vitamin A**

Vitamin A is a fat-soluble vitamin which functions in vision, cellular differentiation, growth, reproduction, boned development, and immune function (Gropper, & Smith, 2013). Two main forms of the vitamin are recognized in foods including retinoids and carotenoids (Byrd-Bredbenner et al., 2013). Retinoids are characterized as the active form of vitamin A, and can be found in dietary sources such as liver, fish, fish oils, fortified milk, and eggs. Carotenoids on the other hand are known as the precursor of vitamin A and make up the yellow-orange pigmentation substance in fruits and vegetables. Dietary sources of carotenoids include a variety of fruits and vegetables such as carrots, spinach, broccoli, sweet potatoes, mangoes, peaches, and cantaloupe (Byrd-Bredbenner et al., 2013). In terms of bone health, a balanced vitamin A is needed for development and maintenance of bone. Although the mechanism of how vitamin A directly impacts bone is still unclear, it is believed to be included in the regulation of osteoblastic and osteoclastic activity. Too little vitamin A is known to result in a negative disproportion in bone deposition and bone degradation, ultimately resulting in greater bone deposition (Gropper, & Smith, 2013). On the contrary,
excessive vitamin A intake a condition known as hypervitaminosis A is known to increase fracture risk and lower bone mineral density and result in inadequate bone growth by excessive osteoclastic activity, and reduced osteoblastic activity (Gropper, & Smith, 2013; Angelo, 2012). Hypervitaminosis A which can only result from excessive intake of vitamin A in the form of retinoids is known to occur either acutely, chronically, or through teratogenic means. Symptoms of acute hypervitaminosis A include gastrointestinal discomfort, headache, blurred vision, and loss of muscle control. This form of toxicity is known to occur if several or a single large dose of vitamin A is ingested over a relatively short period of time. Chronic hypervitaminosis A on the other hand is known occur when repetitive retinoid intakes of ten times the RDA are taken over a prolonged period of time. Symptoms include joint pain, appetite loss, headache, skin conditions, decreased bone minerals, double vision, liver damage, hemorrhage and coma. This form of toxicity can also cause permanent damage if vitamin A intake is not reduced, including damage to the liver, bones, and eyes. Teratogenic effects of hypervitaminosis A which cause birth defects are known to be the most dangerous form of toxicity of vitamin A, and are also known to cause spontaneous abortion amongst pregnant women (Byrd-Bredbenner et al., 2013).

**Vitamin K**

Another fat-soluble vitamin known to affect bone health is vitamin K (Gropper, & Smith, 2013). Two forms of vitamin K that are found in abundance include phylloquinone, and menaquinone (Vermeer, Jie, & Knapen, 1995). The best dietary
sources of vitamin K are found in a variety of vegetables including leafy green vegetables such as collard, and spinach, some salad greens and broccoli (Gropper, & Smith, 2013). It is important to understand that the mechanism by which vitamin K affects bone health is not clearly understood but is known to be a cofactor for the formation carboxylation of Gla residues found on all vitamin K dependent proteins which include osteocalcin, matrix Gla protein, and protein S found in bone, cartilage and dentine (Byrd-Bredbenner et al., 2013; Gropper, & Smith, 2013; Vermeer et al., 1995). The function of these proteins is not well understood, but has been seen to cause changes in bone health by enabling calcium-binding and merge into hydroxyapatite (Byrd-Bredbenner et al., 2013; Angelo, 2012; Bugel, 2008). More specifically, osteocalcin is thought to be concerned with the regulation of bone forming cells, and the growth of hydroxyapatite crystals found in bone architecture, whereas matrix Gla protein is thought to participate in the bone formation and mineralization process (Bugel, 2008). Furthermore, a link between serum vitamin K and bone mineral density and fracture risk has been observed in multiple studies, although controversial views among researchers exist (Gropper, & Smith, 2013; Vermeer et al., 1995). In a cohort study conducted on elderly males and females revealed that low vitamin K intakes were positively associated with increased frequency of hip fractures, however a relationship between low vitamin K intake and low BMD did not exist (Booth et al., 2000). In addition to its function in bone metabolism, vitamin K is also known for its prominent role in the synthesis of blood clotting factors VII, IX, and X, and conversion of preprothrombin to prothrombin, the active blood clotting factor (Byrd-Bredbenner et al., 2013; Gropper, 2013). No UL has been set for vitamin K and is known
to be very readily excreted as compared vitamin A, D, and E (Bryd-Bredbenner et al., 2013).

**Protein Intake**

In general, the typical U.S. diet is high in protein intake in comparison to current recommendations (Ince, Anderson, & Neer, 2013). Approximately 70-100 grams of protein are consumed daily by the average American, whereas only 0.8 grams/kilogram/day of protein equaling approximately 35% of total energy intake is recommended (Ince et al., 2013; Byrd-Bredbenner et al., 2013). An excessive intake of protein is known to have a detrimental effect on an individual’s health status and is particularly associated with declining kidney function and the buildup of nitrogenous wastes in the body. In addition, high protein diets predominantly from animal sources are known to be high in cholesterol and saturated fats and low in fruits, vegetables, subsequently increasing the risk of cardiovascular disease (Byrd-Bredbenner et al., 2013). In terms of bone health, adequate protein is required whereas excessive protein consumption is known to be a risk factor for osteoporosis (Gropper, & Smith, 2013). The mechanism behind high protein diets and bone health include the production of acid in the body which is associated with increased excretion of urinary calcium to provide buffers to neutralize acidity in the blood and consequently leading to loss of bone mass (Eaton, & Eaton, 2000; Byrd-Bredbenner et al., 2013; Gropper, & Smith, 2013). In cases where protein intake has been doubled, a 50% increase in urinary calcium has been observed (Gropper, & Smith, 2013). Furthermore, in westernized nations with high
protein diets a higher incidence of hip fractures has been observed as compared to other nations with low protein diets (Ince et al., 2013). However, researchers have controversial views on high protein diets and bone health, but less concern about this issue is emphasized for those who have adequate calcium intakes (Byrd-Bredbenner et al., 2013).

**Sodium Intake**

Sodium is an essential nutrient widely used in food processing and manufacturing adding flavoring to food, and serving as a preservative, color preservative, and leavening, curing, and wetting agents. The majority of sodium consumed is in the diet is consumed due to food processing accounting for 75-80% of the sodium consumed (Byrd-Bredbenner et al., 2013). In addition, processed foods are also known to be higher in fat and sugar content as compared to non-processed or less processed foods. Highly processed dietary sources include prepared meals, white bread, cookies, chips, soda, and candy (Preidt, 2015).

Sodium found in the diet is in the form of sodium chloride providing 2,300 mg of sodium per a teaspoon and is composed of 40% sodium and 60% chloride (Byrd-Bredbenner et al., 2013; Gropper, & Smith, 2013). The recommendation for sodium is 1500 mg/day for individuals under 51 years old and 1,300 mg/day for individuals 51-70 years of age. In the U.S. over 97% of the population exceeds sodium recommendations. On average, men and women consume 3,830 mg/day and 2,760 mg/day of sodium respectively whereas only 200 mg/day of sodium is needed to maintain physiological
functioning. The UL for sodium is set at 2,300 mg/day. High sodium diets are associated with cardiovascular disease, hypertension, and stroke (Byrd-Bredbenner et al., 2013). In addition, high sodium diets are thought to be similar in magnitude to high protein diets (Eaton, & Eaton, 2000). A sodium intake greater than 2 g/day is associated with an increase excretion in urinary calcium by 20-60 mg/day, and potentially calcium from the bones. Although high sodium intakes and its effect on bone are controversial researchers indicate that high sodium diets are not correlated with osteoporosis (Byrd-Bredbenner et al., 2013; Gropper, & Smith, 2013).

**Caffeine and Soda Consumption**

Caffeine is a stimulant and diuretic known to stimulate the nervous system, increase awareness, and possibly intensify nerve conduction (Byrd-Bredbenner et al., 2013). Caffeine is naturally found, or is added to foods, dietary supplements, and drugs and is commonly found in coffees, teas, sodas, energy drinks, chocolate products, cold and headache medication, as well as various other products (Byrd-Bredbenner et al., 2013; Bailey et al., 2014). In the U.S., caffeine is not tightly regulated and is not required to be displayed Nutrition Fact panels of food; however the FDA has set a limit on caffeine in soda allowing a maximum of 0.02% of the total weight (Bailey et al., 2014). Therefore caffeine intake is variable dependent on the source. Among beverages teas are known to typically contain the least amount of caffeine while energy drinks are known to contain the largest amount of caffeine ranging between 100-240 mg/16 oz. can among popular brands (Byrd-Bredbenner et al., 2013). In the U.S. approximately 89% of the
adult population is known to consume caffeine with caffeine contained beverages accounting 98% of the caffeine consumed. A mean caffeine intake among adults of 186 mg/day is observed (Fulgoni et al., 2015). In pregnant women, caffeine intake of more than 500 mg/day is associated with fertility issues, and increased risk of spontaneous abortion, an infant with low-birth weight, and withdrawal symptoms in the newborn (Byrd-Bredbenner et al., 2013). In terms of bone health, caffeine is known to play a role by causing acidity to bone minerals, decreasing absorption of calcium as well as other nutrients such as iron and zinc and increasing urinary calcium excretion (Byrd-Bredbenner et al., 2013; Gropper, & Smith, 2013). Another possible mechanism by which caffeine intake has been shown to be detrimental is the quantities it is consumed in coupled with the declining rate of calcium rich sources which are known to be a modifiable risk factor of osteoporosis. For instance, in the U.S. caffeine intakes have increased approximately 118% from 1970-1997 while at the same time milk consumption decreased by 23 percent (Golden, 2000). Recommendations for caffeine intake vary depending on the source. For example, coffee intake of more than three cups per day has been found to interfere with bone health, whereas the number of cola drinks that is found to have similar effects is five cola drinks per a week (National Osteoporosis Foundation, n.d.a; National Osteoporosis Foundation, n.d.b). In general, recommendations are set to the threshold of 300-400 mg which has been found to increase urinary calcium excretion by ten mg/day. Previous studies have shown caffeine to increase the risk of hip fracture in women with low calcium intakes, but caffeine is not thought to be strongly correlated with an individual’s risk of developing osteoporosis. Up to date research is needed to
further evaluate caffeine’s effect on bone health (Gropper, & Smith, 2013). In general, adverse effects of caffeine are not observed in caffeine intakes up to 400 mg/day (Fulgoni et al., 2015).

**Physical Activity**

An absence or low amount of physical activity has been associated with detrimental effects on bone health (Gropper, & Smith, 2013). Whereas a regular incorporation of physical activity including activities of weight bearing endurance, activities involving jumping, and resistance exercises such as tennis, jogging, walking, running, dancing, basketball, volleyball or weight training have be shown to provide a protective edge in terms of bone health. The mechanism behind this practice is supported by two key reasons that are seen by individuals who incorporate regular physical activity and their bone which include decreased bone loss and increasing bone mineral density by stimulating bone formation in response to mechanical stress (Gropper, & Smith, 2013; Angelo, 2012). Bone formation is especially pronounced on areas of the hip and spine which have been known to be prone to osteoporotic related fractures. In addition greater muscular strength, balance and physical coordination gained through exercise provides an individual the ability to withstand falls thereby lowering their risk of bone fractures (Gropper, & Smith, 2013; Kamel, 2006). A previous meta-analysis study revealed an approximately 1% decreased bone loss in pre and postmenopausal women, and an approximately 0.5% increase in cortical bone density in older women (Warburton, Nicol, & Bredin, 2006). Recommendations set by the American College of Sports Medicine
states that moderate to high intensity of physical activity for 30-60 minutes a day and include a combination of activities of weight bearing endurance, resistance, and ones that involve jumping (Angelo, 2012). Whereas, the National Osteoporosis Foundation recommends individuals to participate in weight bearing exercises for 30 minutes on most of the days in a week, muscle strengthening/resistance training 2-3 times a week, and exercises that focus on balance, posture, and function as often as needed or everyday (National Osteoporosis Foundation, n.d.c). In addition to beneficial effects on bone health, regular physical activity has been shown to be effective as prevention measures of chronic diseases such as cardiovascular disease, hypertension, diabetes, breast and colon cancer, and obesity and is observed to reduce mortality (Warburton et al., 2006).

**Amenorrhea**

Amenorrhea is a condition characterized by the absence of three or more sequential menstrual cycles in females (Byrd-Bredbenner et al., 2013). Manifestation of amenorrhea can occur through eating disorders such as anorexia nervosa or over exercise (Byrd-Bredbenner et al., 2013; Gropper, & Smith, 2013). In general in the U.S., eating disorders affect more than five million individuals, most prevalently affecting the female population and developing in adolescence or in the early adulthood period (Byrd-Bredbenner et al., 2013). Anorexia nervosa is a multifactorial eating disorder characterized excessive weight loss, misrepresented body image, and severe fear of gaining weight and obesity. Typical dietary intakes among anorectics include nutritional deficient diets which less than 800 kilocalories per a day. Criteria for diagnosis based on
Diagnostic and Statistical Manual of Mental Disorders IV includes an individual’s refusal to maintain weight at or above at least 85% of normal expect weight for height. Due to the chronic and relapsing nature of this illness only approximately 40-50% of the individuals affected by this condition completely recover, while 10-15% is victims of premature death, and untreated individuals often die prior to the age of thirty. An array of medical complications arise from anorexia nervosa known to have unfavorable effect on bone health, gastrointestinal tract, cardiovascular and metabolic systems, blood, muscle and the brain (Gropper, & Smith, 2013).

In terms of bone health, anorexia nervosa is associated with increased bone loss due to low circulating levels of estrogen coupled with the loss of their menstrual cycle due to low body weight, low fat composition and mental stress of the illness increases their susceptibility to osteoporosis (Byrd-Bredbenner et al., 2013; Gropper, & Smith, 2013). This disorder when present in adolescent females further exacerbates negative bone resorption by preventing adequate attainment of PBM (Gropper, & Smith, 2013). In the U.S. anorexia nervosa is thought to affect at least every one of 200 adolescent females (Byrd-Bredbenner et al., 2013). Similar to anorexia nervosa, over exercise is also associated with amenorrhea (Gropper, & Smith, 2013). This also is detrimental to bone health due to loss of estrogen which when in adequate levels is known to promote bone formation and bone mineralization, especially if an individual’s calcium status is already deficient (Gropper, & Smith, 2013; Angelo, 2012).
Alcohol

Alcohol is non-essential nutrient and is considered a narcotic which acts upon the body by reducing sensations, consciousness and depressing the central nervous system. In the body alcohol is absorbed through diffusion in the gastrointestinal tract, and acts on food by reducing absorption. Alcohol is a substance that commonly abused in the world today. It is the third most prominent cause of preventable deaths among the adult population, and is most commonly abused substance in the United States. Approximately, 60% of U.S. adults report consuming alcohol through the means of beverages such as beer, spirits, wine and hard liquor providing approximately 3% of total energy intake among the consuming population (Byrd-Bredbenner et al., 2013). Recommendations for alcohol propose no more than a daily intake of one standard drink for women, and no more than 2 standard drinks for men, however in terms of bone health a daily intake of more than 2 drinks for women, and 3 drinks for men is deemed to cause detrimental consequences to bone, and is found to increase the risk of falls (Byrd-Bredbenner et al., 2013; National Osteoporosis Foundation, 2014; Mikosch, 2014). Standard-sized drinks are equivalent to a 12 fluid oz. of beer, five fluid oz. of wine, or 1.5 fluid oz. of liquor. Excessive alcohol consumption is linked to adverse effects of nearly every organ in the body and even known to cause death. In addition, alcohol can lead to nutrient deficiencies of thiamin, niacin, folate, and vitamins B-6, B-12, A, D, E, and K along with mineral deficiencies in calcium, magnesium, zinc and iron (Byrd-Bredbenner et al., 2013). In terms of bone health, excessive alcohol consumption is linked with reduced bone density, decreased osteoblastic activity and metabolic irregularities such as
a vitamin D deficiency which negatively affect bone health by bone loss. However, it should be noted that a chronic light usage of alcohol has been seen to have positive outcome in terms of bone density as well as with cardiovascular disease (Angelo, 2012; Byrd-Bredbenner et al., 2013).

**Smoking**

Another unhealthy lifestyle factor that is prevalent in the U.S. today is smoking, and is a leading cause of morbidity and mortality. In the United States 21.6% males and 16.5% of females are smokers. The effects of smoking are known to cause various adverse effects among the using population including cardiovascular disease, lung disease, lung cancer, and numerous other health consequences, especially among women (Syamlal, Mazurek, & Dube 2014). In terms of bone health, the nicotine and the non-nicotine components of cigarettes are thought to be responsible for a decline in bone health, however research regarding the mechanism is premature and uncertain (Wong, Christine, & Wark, 2007).

Well discovered in the world today, smoking is known to have a negative impact on bone status as it is correlated with a significant decrease bone density and bone formation, increase in bone resorption ultimately leading to osteoporosis and increased risk fracture (Angelo, 2012; Gropper, & Smith, 2013; Wong et al., 2007). The Dubbo Osteoporosis Epidemiologic study (DOES) among the elderly found that smoking was positively related to 5-8% lower bone mineral density at sites of the vertebrae and femoral neck of the femur, and women smokers experienced almost twice the amount of
bone loss at the femoral neck of the femur as compared to male smokers (Nguyen et al., 1994). In addition, a more pronounced relationship is seen with women with a BMI of less than 25 kg/m² and women who have breastfed (Wong et al., 2007). Furthermore, smoking is known to cause change in 1,25-dihydroxyvitamin D and estrogen further exacerbating its negative effects on bone health (Angelo, 2012). In addition, women who smoke have a greater risk of developing osteoporosis due to menopausal changes associated ageing (Gropper, & Smith, 2013). However, cessation of smoking is known to partially reverse bone loss associated with smoking, and can provide many benefits to an individual’s overall health status (Angelo, 2012; Wong et al., 2007).

**Dietary Patterns Among College Students**

The transition from high school into early adulthood is faced with many challenges. Approximately 60% of high school graduates choose to attend college, a journey that is filled with a new realm of independence, and multiple opportunities. This transition is a crucial developmental milestone in the lives of young adults and can provide individuals with many opportunities to develop healthful behaviors (Fromme, Corbin, & Kruse, 2008; Debate, Topping, & Sargent, 2001). In spite of this however, data gathered from the 1995 College Health Risk Behavior Survey revealed college students participated in lifestyle behaviors deemed to place them at risk for developing major health issues (Debate et al., 2001). The development of eating habits is one that occurs during this period, and continues into adulthood. The importance of dietary practices is stressed due to relationship between healthy dietary practices and the
protective role against chronic diseases observed later in life. In general, dietary patterns of college students are high in total fat, saturated fat, cholesterol, and sodium, and relatively low in fruits and vegetables (Haberman, & Luffey, 1998). In fact, a study conducted by researchers of Oregon State University found that college students are not meeting the U.S. Department of Agriculture guidelines, and are not consuming a serving of fruit or vegetables daily. This study also found on a weekly average male students consumed five servings of fruits, and vegetables combined while female students only consumed four servings of fruits and vegetables, and also had a low fiber intake (Li et al., 2011). Furthermore, in the U.S. less than 50% of young adults ages 20-29 are known to not even consume one serving of dairy products daily (Larson et al., 2009). In addition, unhealthy diets of college students often include skipping meals, a lack of variety of foods in the diet, common consumption of fast foods, lack of awareness and knowledge of food recommendations and guidelines. A previous study revealed that only approximately 37% of students consumed breakfast on a regular basis, while 32% of students reported regularly eating fast food, and 42% of students reported eating fast food occasionally (Debate et al., 2001). Furthermore, in the college student population individuals often face many difficulties to maintain a healthy weight; approximately 30% of college students are either overweight or obese (Racette, Desusinger, Strube, Highstein, & Deusinger, 2008).
Dietary Patterns Among Female College Students

In terms of osteoporosis, females are known to be more vulnerable to the disease due to physiological changes that occur during their life span (Gropper, & Smith, 2013; Cleveland Clinic, 2012). Therefore their ability to achieve PBM by the third decade of life is very crucial in the prevention of osteoporosis later in life (Larson et al., 2009; Glorieux et al., 2012). Similar to the overall dietary pattern among college students, females tend to follow a similar diet pattern during these years. A study conducted on college women revealed that students were non-compliant with to the Dietary Guidelines for Americans. Specifically, guidelines that called for eating a variety of foods, moderately using sodium and sugar in the diet, consuming grains, vegetables and fruit, and choosing a diet low in fat were not adhered to keenly, with a noncompliance ranging from 65%-100% amongst the dietary guidelines. In addition, 25% of female college student participates were determined to be overweight (Anding, Suminski, & Boss, 2001). A study conducted by Racette et al. (2008) on 204 college students revealed students increased weight and BMI significantly from their freshman through their senior year.

Calcium intake in female college students. Previous statistics have indicated low calcium intake among the American population. Approximately 25% of American adult women consume only around 600 mg of calcium on a daily basis (Byrd-Bredbenner et al., 2013). In 2010, the Dietary Guidelines for Americans raised public health concerns regarding low intakes of calcium, as well as vitamin D and other key nutrients
important to overall health observed in a majority of Americans (Keast, Fulgoni, Nicklas, & O’Neil, 2013). Similar perspectives are represented in the scientific report by the Dietary Guidelines Advisory Committee in 2015. Calcium intakes were significantly below the estimated average requirement, particularly among the adolescent female, and adult population (Dietary guidelines, 2015). In the young adult female population, ages 19-30 years old research has found that only 21% consume recommended amounts of calcium (Larson et al., 2009). A recent study by Ediriweera de Silva et al. (2014) conducted on female college students in Sri Lanka found the mean calcium intake among the population to be significantly inadequate at 528 mg/day. In addition, this study also found that more than 80% of this population did not meet the RDA for calcium.

**Vitamin D intake in female college students.** Another nutrient known to be a public health concern, as well as a crucial component in bone health is vitamin D (Keast et al., 2013; Holick, 2007). Across the world vitamin D deficiency or insufficiency is known to affect one billion individuals. In the U.S. and Europe vitamin D deficiency is said to affect 40 to 100% of the elderly population living in outside of nursing homes and 50% of postmenopausal women taking pharmaceutical medication for osteoporosis (Holick, 2007). A previous study conducted on college female students between the ages of 19-27 found that 97.2% of the population which consisted of healthy individuals was either vitamin D deficient or insufficient with 50.7% of the population having severe vitamin D deficiency (Sharif, & Rizk, 2011). In addition, consumption of dairy products has also been found to be inadequate among this population. Approximately 43% of young females’ ages 20-29 years old consume less than one serving of dairy per a day.
(Larson et al., 2009). A previous study conducted among nursing students revealed that 92.6% of the participants did not meet recommendations for dairy, a good source of both vitamin D and calcium (Van de Berg, Okeya, Dannhauser, & Nel, 2012; Byrd-Bredbenner et al., 2013). Furthermore, a shift from milk and milk products which provide good sources of calcium and vitamin D has been observed since the early 1990’s along with the increase in the consumption of less nutrient dense beverages and foods in age groups 2-18 years old (Keast et al., 2013).

**Caffeine and soda consumption in female college students.** According to the 2003-2006 NHANES, soft drinks composed 19.2% of total sugars, and 29.7% of added sugars in children 2-18 years of age, ranking in the top five most consumed food group providing energy and nutrients, and number one as far as total and added sugars (Keast et al., 2013). Generally speaking caffeine intakes do not usually surpass safe levels of consumption among any age. Less than 10% of individuals consume more than moderate intakes of caffeine exceeding 400 mg/day. These individuals are more likely to be among ages 31-70 years old where caffeine intake is known to peak (Dietary guidelines, 2015). However, in the college population 50% of students report consuming at least, one energy drink per a month during the regular semester (Malinauska, Aeby, Overton, Carpenter-Aeby, & Heidal, 2007). In addition, according to the NHANES 2007-2010 report caffeine consumption was the highest in females among the ages of 19-30 with a mean daily caffeine intake of 134.9 mg/day among caffeine-containing energy products users in addition to traditional caffeine sources like coffee, tea, and sodas (Bailey et al., 2014). For perspective, a study conducted by Massey and Wise (1984) found that
calcium excretion was significant with increasing doses of caffeine in healthy young females, where the mean calcium excretion three hours after a caffeine dose of 150 mg and 300 mg was 27.2 mg and 45.3 mg, respectively.

**Protein and sodium intake in female college students.** In the U.S. the excessive consumption of protein and sodium is present (Ince et al., 2013; Dietary guidelines, 2015). In fact sodium generally is consumed in excess far above the UL across all age groups, and due to its overconsumption has become a significant public health concern (Dietary guidelines, 2015). A study conducted on future health care professionals in comparison to other students revealed no significant differences between protein consumption, however both types’ students were found to exceed the dietary reference intakes for protein (Irazusta et al., 2006; Brown et al., 2014). In general, the RDA for protein and the UL for sodium for females ranging from 19-30 years old are 46 and 2.3 grams/day (Brown et al., 2014). In a study conducted by Myung-Soo (2007) on female college students of different body type’s protein and sodium intake was found to have a mean range between 445.14-69.9 and 3.1-3.7 grams/day, respectively. In addition, this study found participants only consumed animal product proteins 1-2 times a week.

**Dietary Pattern and Chronic Diseases among Individuals with Risk Factors**

Previous studies have shown a relationship between risk factors of chronic diseases and individuals participating in risk reducing behaviors such as modification of their dietary pattern. A large study on individuals without diagnosed cardiovascular
disease focused on evaluating family history of cardiovascular disease and heart disease risk reducing behaviors. This study found that 28% of participants were at moderate risk of cardiovascular disease, having one first-degree relative with heart disease, and 15% of participants were at high risk of cardiovascular disease, having more than 2 first-degree relatives with heart disease. Results indicated that behavior modification such as aspirin use, cholesterol testing, eating a less high fat containing foods, and increasing fruit and vegetable intake was positively associated with individuals with increased risk of cardiovascular disease (McCusker et al., 2004). Similarly, another study found that approximately 30% of U.S. adults had prediabetes through 2005-2006. Results indicated that approximately 50% of individuals with prediabetes participated in diabetes risk reducing behaviors in the last year. In addition, 54.7% of individuals with prediabetes reported participating in reducing fat or calories consumed (Geiss et al., 2010). However, similar research regarding osteoporosis risk factors and the relation to osteoporosis risk reducing behaviors does not exist.

**Perception, Knowledge and Behavior of Osteoporosis**

The intimately linked relationship between perception and behavior has been commonly recognized by the world today. A study by Dijksterhuis and Van Knippenberg (1998) found a positive relationship between the magnitudes of the perceptual effect and behavioral effect. This study also went a step further by generalizing the link between perception and behavior to behavior of larger complexity. In regards to chronic diseases including osteoporosis, coronary artery disease, breast and
colorectal cancer, depression and cerebrovascular disease research have found that the magnitude that an individual perceives their risk of acquiring a disease is an important factor with following preventative behaviors (Fiandt, Pullen, & Walker, 1999). Other studies regarding cardiovascular disease and diabetes have also found that a positive family history for the disease is associated with increased perceived risk of the disease (Claassen et al., 2011; Gallivan, Brown, Greenberg, & Clark, 2009; Hunt, Davison, Emslie, & Ford, 2000).

It has been found that there is a positive relationship between risk perception and FHO and knowledge of osteoporosis. A recent study conducted in Mexico City revealed that over 50% of participants were able to recognize family history as a risk factor of osteoporosis. This study also found that FHO was considered to be one of the most important variables in regards to risk perception of the disease by participants (Clark, & Lavielle, 2015). Another study conducted on 452 premenopausal women found a positive relationship between knowledge and risk reducing behaviors such as calcium intake and exercise (Blalock et al., 1996). However, many women still tend to underestimate osteoporosis and tend to have lower perceived susceptibility and less than mediocre knowledge of the disease (Hsieh et al., 2001; Ediriweera de Silva et al., 2014). A previous study evaluating the health beliefs and attitudes of older women towards preventing osteoporosis found that only 29% of participants perceived susceptibility to the disease, and less than half of the participants were taking measures towards preventing osteoporosis. In addition, these participants also disclosed that they were less concerned about osteoporosis as compared to other chronic diseases such as
cardiovascular disease, cancer, and neurological diseases (Hsieh et al., 2001). Furthermore, research from a community sample revealed that the majority of women tend to rate their perceived risk of osteoporosis less than other women their age (Gerend, Erchull, Aiken, & Maner, 2006). Another recent study conducted by Ediriweera de Silva et al. (2014) found that 40.8% of young females entering medical school in Sri Lanka had poor knowledge of osteoporosis with the majority of participants with a low perceived susceptibility for osteoporosis even though preventative measures against the disease and calcium intake were inadequate.
CHAPTER III

METHODOLOGY

Research Design

The purpose of this study was to assess differences in knowledge and perception about osteoporosis and risk reducing behaviors of those with FHO in comparison with those without family history in female college students. The study used a cross-sectional survey design. Independent variables include the groups of female college students with FHO and without FHO. FHO was defined as having a diagnosis of osteoporosis and/or hip fracture of first and second-degree relatives. Dependent variables included were knowledge and perception of osteoporosis, modifiable risk factors of osteoporosis, and perception on osteoporosis risk reducing behaviors such as physical activity, alcohol consumption, smoking, and soda, coffee, and energy drink consumption.

Research Sample

The participants in the current study were female undergraduate and graduate students, at least 18 years old enrolled at Kent State University, a public Midwestern state university, in Kent, Ohio during the Spring 2016 semester. Inclusion criteria included part time and full time female undergraduate and graduate students of Kent State University both with and without FHO.

Survey Questionnaire

The survey, included in Appendix B, consisted of nine main sections including: general demographics, questions about osteoporosis information, risk factors of
osteoporosis, calcium questionnaire, knowledge and perception about osteoporosis, and perception on risk reducing behaviors against osteoporosis development.

**Part I: General Demographics**

Part I of the survey included general demographic questions such as age, sex, ethnicity, height, weight, class ranking, and if they have ever taken a college nutrition course. If the participant did not meet the criteria for age (under 18 years of age) or sex (indicating that they are either of male or neither sex), the survey was terminated. However, if the participant did meet the age and sex criteria, they answered a total of seven questions in this section.

**Part II: Information Sources Questions**

Part II of the survey included questions where and from whom the participant received information about osteoporosis. Participants in this section answered three questions, and were prompted to answer one additional question if they indicated that they have been exposed to information about osteoporosis, answering a total of four questions in this section.

**Part III: History of Previous Fracture and FHO**

Part III of the survey focused on FHO and family history of fragility fractures. These questions were used to determine if the participant did or did not have a positive FHO. This section contained a total of two questions.
Part IV: Modifiable Risk Factors

Part IV of the survey consisted of questions regarding modifiable risk factors such as sun exposure, alcohol intake, smoking status, coffee intake, tea intake, soda intake, energy drink consumption, and exercise status. In this section the participant had the potential to answer a maximum of 13 questions. Among modifiable risk factors, calcium intake was separately surveyed in Part V.

Part V: Calcium Questionnaire

Part V focused on calcium intake from dairy and non-dairy food sources. Questions in this section were designed to estimate the respondent’s calcium intake within the past 24 hours. A validated calcium questionnaire from the Dairy Council of California (2013) was utilized in this section. This survey previously has been assessed for validity and reliability in various samples including women from a variety of age groups. Participants, in this section answer a total of seven questions on 26 calcium containing items.

Part VI: Knowledge Questions

Part VI had total of 17 questions to assess knowledge of participants about osteoporosis and related issues. This part of the questionnaire was divided into three different sections:

- General aspect of osteoporosis
- Non-modifiable and modifiable risk factors of osteoporosis
• Identification of calcium-rich foods

**Part VII: General Perception Questions**

Part VII of the survey examined the participant’s general perception of osteoporosis and the seriousness of osteoporosis as compared to other chronic diseases through 2 questions based on a modified 5-point Likert Scale where (1) was strongly agree and (5) was strongly disagree to the statements.

**Part VIII: Risk Perception**

Part VIII of this survey focused on the participant’s risk perception of osteoporosis. This section also utilized the modified 5-point Likert Scale where (1) was strongly agree to the statement, and (5) indicated that the participant strongly disagreed with the statement. This section consisted of a total of six questions.

**Part IX: Perception on Risk Reducing Behaviors**

Part IX focused on how participants perceive their involvement in risk reducing behaviors of osteoporosis. This section consisted of nine questions asking if participants have made lifestyle changes in their lifestyle to reduce modifiable risks against osteoporosis development later in life. The modified 5-point Likert Scale was used where (1) was strongly agree to the statement, and (5) indicated that the participant strongly disagrees with the statement.
Procedures

The survey was administered using Qualtrics (v.1.817s), an online survey software program. The study was approved from the Kent State University Institutional Review Board. A request was submitted to the Kent State University Registrar’s office for 10,000 email addresses and Flashline user names of undergraduate and graduate students that were enrolled in the Spring 2016 semester. An email invitation as well as personal announcement in Flashline to an electronic questionnaire was sent to possible participants explaining the study, requesting participation, and ensuring anonymity of the responses with a link connected to the Qualtrics survey with an attached electronic consent form. Participants were informed that those who complete the survey would be given the option to be entered into a drawing for one of four $25.00 Amazon gift cards. The survey was open for three weeks with two weekly email reminders sent through the survey period.

Statistical Analysis

Only completed surveys were included in data analysis. Analysis of the results was performed to determine significance following the three weeks of data collection. Statistical analysis was completed using the Statistical Package for the Social Sciences (SPSS, version 22, Armonk, NY). Descriptive statistics were used to calculate means, standard deviations, frequencies and percentages for analysis of demographics, general questions, FHO, modifiable risk factors, and dietary intake variables. Independent t-tests were used to compare the means of knowledge questions, Likert scale responses for perception and risk perception questions, and perceived risk reducing behavior questions
among female college students with FHO, and female college students without FHO. Chi-squared was used to determine if there were differences in smoking, alcohol consumption, coffee consumption, soda consumption, and physical activity in two groups. A significance of $P \leq 0.05$ was set for both t-test and chi-squared measurements.
CHAPTER IV
JOURNAL ARTICLE

Introduction

Osteoporosis is a common progressive skeletal disorder that is characterized by decreased bone strength, low bone mass, deterioration of bone tissue, and increased risk of sudden and unexpected fractures in any life stage but especially in postmenopausal women and the geriatric population (Janiszewska et al., 2015; Siris et al., 2014). Currently, in the U.S., osteoporosis and low bone density, a precursor to osteoporosis, affects approximately 54 million individuals and over 30% of women over the age of 50, resulting in more than two million fractures annually as well as other detrimental consequences such as becoming bedridden, relocation, and others (NOF, 2014a; National Osteoporosis Foundation [NOF], 2015; Siris et al., 2014). These debilitating diseases are expected to increase and affect as many as 61 million Americans by the year 2050 (NOF, 2015).

Due to the progressive silent nature of this disease, osteoporosis is clinically under recognized and untreated and is largely preventable through diet, exercise, and social behaviors (Lin, & Lane, 2004; Fulgoni et al., 2015). In order to combat this disease preventative measures of osteoporosis should be taken from years of puberty through young adulthood and until the age of 30 to obtain the highest potential peak bone mass (PBM) (Cleveland Clinic, 2010a; Ediriweera de Silva, 2015; Siris et al., 2014). PBM which accounts for more than half of the variability of adult bone mass is defined as the amount of bony tissue present at the end of skeletal maturation is affected by various
factors such as genetics, gender, ethnicity, calcium intake, physical activity, and smoking status (Valimaki et al., 1994; Rizzoli, & Bonjour, 1999; Rabinovich, 2004; Walker et al., 2008).

Family history is one of the most important risk factors of osteoporosis development (Iqbal, 2000). In fact, 70% of osteoporosis cases are the effect of genetic predisposition and numerous studies have documented the relationship between positive FHO and lower bone mineral density in women (Iqbal, 2000; Orwoll, & Bliziotes, 2003). Young adults up to the age of 30 have the opportunity to acquire their highest potential peak bone mass which can significantly reduce their risk of developing osteoporosis later in life. However, a body of research indicates that young adults are not taking advantage of engaging in bone friendly behaviors that could reduce their risk of developing this disease. Unhealthful trends seen among this population include increased soda consumption with decreased milk intake, overall low calcium intake, and a high prevalence of vitamin D deficiency (Wyshak, 2000; Forshee, & Storey, 2003; Sharif, & Rizk, 2011). In addition, caffeine intake is found to be the highest among females ages 19-30 as compared to any other age group (Bailey et al., 2014). Literature shows majority of women underestimate osteoporosis, tend to have lowered perceived susceptibility, and inadequate knowledge of osteoporosis (Hsieh et al., 2001; Ediriweera de Silva et al., 2014). As enrollment continues to increase with female enrollment and 18-24 year old population accounting for a majority of college students a focus on increasing PBM is critical (Fast facts: Back to school statistics, n.d.). Furthermore, previous studies have shown that family history of chronic diseases, such as
cardiovascular disease, is linked to increased engagement in preventative behaviors such as diet modifications (McCusker et al., 2004). However, there is limited research that explores the link between FHO, risk perception, knowledge of osteoporosis, and risk reducing behaviors, especially among the college female population (Clark, & Lavielle, 2015; Blalock et al., 1996). Therefore, the primary purpose of this study was to assess knowledge and perception about osteoporosis, and risk reducing behaviors between female college students with family history of osteoporosis and those without family history of osteoporosis. The secondary objective of this study was to assess modifiable risk factors between the two groups.

Methodology

The study used a cross-sectional survey design. Independent variables include groups of female college students with a positive family history of osteoporosis (FHO), which was defined as having a diagnosis of osteoporosis and/or hip fracture of first- and second-degree relatives, and those without FHO. Dependent variables included were knowledge and perception of osteoporosis, modifiable risk factors of osteoporosis, and perception on osteoporosis risk reducing behaviors such as physical activity, alcohol consumption, smoking, and soda, coffee, and energy drink consumption.

Research Sample

The participants in the current study were female undergraduate and graduate students, at least 18 years old enrolled at Kent State University, a public Midwestern state university, in Kent, Ohio during the spring 2016 semester. Inclusion criteria included
part time and full time female undergraduate and graduate students of Kent State University both with and without FHO.

**Procedures**

The survey was administered using Qualtrics (v.1.817s), an online survey software program. The study was approved from the Kent State University Institutional Review Board. An email invitation, as well as personal announcement in Flashline to an electronic questionnaire was sent to 10,000 possible participants explaining the study, requesting participation, and ensuring anonymity of the responses with a link connected to the Qualtrics survey with an attached electronic consent form. Participants were informed that those who complete the survey would be given the option to be entered into a drawing for one of four $25.00 Amazon gift cards. The survey was open for three weeks with two weekly email reminders sent through the survey period.

**Survey Questionnaire**

The survey, included in Appendix B, consisted of 67 potential questions throughout nine main sections including: general demographics, questions about osteoporosis information, risk factors of osteoporosis, calcium questionnaire, knowledge and perception about osteoporosis, and perception on risk reducing behaviors against osteoporosis development. Part I of the survey included general demographic questions such as age, sex, ethnicity, height, weight, class ranking, and if they have ever taken a college nutrition course. If the participant did not meet the criteria for age (under 18 years of age) or sex (indicating that they are either of male or neither sex), the survey was
terminated. Part II of the survey included questions where and from whom the participant received information about osteoporosis. Part III of the survey focused on FHO and family history of fragility fractures which were used to determine if the participant did or did not have a positive FHO. Part IV of the survey consisted of questions regarding modifiable risk factors such as sun exposure, alcohol intake, smoking status, coffee intake, soda intake, energy drink consumption, and exercise status that the participants were currently engaged in. Among modifiable risk factors, calcium intake was separately surveyed in Part V which focused on calcium intake from dairy and non-dairy food sources. Questions in this section were designed to estimate the respondent’s calcium intake within the past 24 hours. A validated calcium questionnaire from the Dairy Council of California (2013) was utilized in this section. Part VI was used to assess knowledge of participants about osteoporosis and related issues. This part of the questionnaire was divided into three different sections: general aspect of osteoporosis, non-modifiable and modifiable risk factors of osteoporosis, and identification of calcium-rich foods. Part VII and Part VIII of the survey examined the participant’s general perception of osteoporosis and the seriousness of osteoporosis as compared to other chronic diseases and the participant’s risk perception of osteoporosis, respectively. These sections utilized the modified 5-point Likert Scale where (1) was strongly agree to the statement, and (5) indicated that the participant strongly disagreed to the statement. Part IX focused on how participants perceive their involvement in risk reducing behaviors of osteoporosis. This section consisted of questions asking if participants have made lifestyle changes in their lifestyle to reduce modifiable risks against osteoporosis
development later in life, and also utilized a modified Likert Scale where (1) was strongly agree to the statement, and (5) indicated that the participant strongly disagreed to the statement.

**Statistical Analysis**

Only completed surveys were included in data analysis. Analysis of the results was performed to determine significance following the three weeks of data collection. Statistical analysis was completed using the Statistical Package for the Social Sciences (SPSS, version 22, Armonk, NY). Descriptive statistics were used to calculate means, standard deviations, frequencies and percentages for analysis of demographics, general questions, FHO, modifiable risk factors, and dietary intake variables. Independent t-tests were used to compare the means of knowledge questions, Likert scale responses for perception and risk perception questions, and perceived risk reducing behavior questions among female college students with FHO, and female college students without FHO. Chi-squared was used to determine if there were differences in smoking, alcohol consumption, coffee consumption, soda consumption, and physical activity in two groups. A significance of $P \leq 0.05$ was set for both t-test and chi-squared measurements.

**Results**

Six-hundred and thirteen students began the survey, resulting in a 6.13% response rate. Participants were excluded from the study if they were under the age of 18, and if they were male or neither gender eliminating $n=2$ (0.33%) and $n=3$ (0.5%) individuals, respectively. The remaining 608 participants continued on through the rest of survey
answering questions related to demographics, family history, non-modifiable risk factors, knowledge, perception, and perception in risk reducing behavior of osteoporosis. Incomplete survey responses were excluded from data analysis once the study concluded, leaving only 579 participants, resulting in a 94.45% completion rate.

**Family History of Osteoporosis**

FHO was determined by participant’s answers to questions asking if anyone in their family (defined as parents, siblings, grandparents, and aunts) had a history of osteoporosis or fragility fractures. Out of 579 participants 83.6% (n=484) were identified to have no FHO, while 16.4% (n=95) were identified to have positive FHO.

**Demographics**

The demographic data of the participants is highlighted in Table 1. The mean age of the sample was 24.03±7.8. In addition, a majority of participants were Caucasian, followed by African American, Asian, other, and Hispanic. Eighty-three percent of survey participants were undergraduate female students while the remaining 17.2% were graduate students. Approximately 40% of participants in this study took a college nutrition class. The mean BMI of the participants was 25.65±6.7 with more than half of the participants (56.7%, n=317) reporting a BMI in the normal range of 18-24.9.
Table 1

*General Demographics of Female College Students Surveyed*

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<td>21</td>
<td>21.1 (20)</td>
<td>22.6 (109)</td>
<td>22.3 (129)</td>
</tr>
<tr>
<td>22</td>
<td>15.8 (15)</td>
<td>18.2 (88)</td>
<td>17.8 (103)</td>
</tr>
<tr>
<td>23</td>
<td>8.4 (8)</td>
<td>7.9 (38)</td>
<td>8 (46)</td>
</tr>
<tr>
<td>24</td>
<td>3.2 (3)</td>
<td>2.1 (10)</td>
<td>2.2 (13)</td>
</tr>
<tr>
<td>25</td>
<td>1.1 (1)</td>
<td>2.7 (13)</td>
<td>2.4 (14)</td>
</tr>
<tr>
<td>≥26</td>
<td>25.2 (24)</td>
<td>18 (87)</td>
<td>19.3 (111)</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>90.5 (86)</td>
<td>84.1 (407)</td>
<td>85.3 (493)</td>
</tr>
<tr>
<td>Asian</td>
<td>0 (0)</td>
<td>4.3 (21)</td>
<td>3.6 (21)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>2.1 (2)</td>
<td>2.5 (12)</td>
<td>2.4 (14)</td>
</tr>
<tr>
<td>African American</td>
<td>3.2 (3.2)</td>
<td>5.8 (28)</td>
<td>5.4 (31)</td>
</tr>
<tr>
<td>Other</td>
<td>4.2 (4)</td>
<td>3.1 (15)</td>
<td>3.3 (19)</td>
</tr>
<tr>
<td>Class rank</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Freshman</td>
<td>1.1 (1)</td>
<td>1.0 (5)</td>
<td>1.0 (6)</td>
</tr>
<tr>
<td>Sophomore</td>
<td>12.6 (12)</td>
<td>16.3 (79)</td>
<td>15.7 (91)</td>
</tr>
<tr>
<td>Junior</td>
<td>33.7 (32)</td>
<td>27.7 (134)</td>
<td>28.7 (166)</td>
</tr>
<tr>
<td>Senior</td>
<td>33.7 (32)</td>
<td>38.0 (184)</td>
<td>37.3 (216)</td>
</tr>
<tr>
<td>Graduate student</td>
<td>18.9 (18)</td>
<td>16.9 (82)</td>
<td>17.3 (100)</td>
</tr>
<tr>
<td>College nutrition class</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>44.2 (42)</td>
<td>37.4 (181)</td>
<td>38.5 (223)</td>
</tr>
<tr>
<td>No</td>
<td>55.8 (53)</td>
<td>62.6 (303)</td>
<td>61.5 (356)</td>
</tr>
<tr>
<td>Body Mass Index</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;18</td>
<td>1.1 (1)</td>
<td>2.6 (12)</td>
<td>2.3 (13)</td>
</tr>
<tr>
<td>18-24.9</td>
<td>50.0 (47)</td>
<td>58.1 (270)</td>
<td>56.7 (317)</td>
</tr>
<tr>
<td>25-29.9</td>
<td>27.7 (26)</td>
<td>21.3 (99)</td>
<td>22.4 (125)</td>
</tr>
<tr>
<td>30-34.9</td>
<td>14.9 (14)</td>
<td>7.1 (33)</td>
<td>8.4 (47)</td>
</tr>
<tr>
<td>35-39.9</td>
<td>4.3 (4)</td>
<td>6.0 (28)</td>
<td>5.7 (32)</td>
</tr>
<tr>
<td>≥40</td>
<td>2.1 (2)</td>
<td>4.9 (23)</td>
<td>4.5 (25)</td>
</tr>
</tbody>
</table>

*Abbreviations.* (+) positive; (-) negative; FHO, family history of osteoporosis.
Sources of Information about Osteoporosis

A majority of participants (60.7%, n=352) indicated that they have been exposed to information about osteoporosis. Sources from which those female participants obtained information about osteoporosis are highlighted in Table 2. As shown, friends and family was the major source of information related to osteoporosis followed by television and magazines. Approximately 40% (n=122) of participants indicated information related to osteoporosis was obtained through health professionals including nurses, doctors, and dietitians. However, from the sample as a whole only 14.7% reported being informed that they are at risk for developing osteoporosis by a healthcare professional, and a mere 13.5% (n= 78) of all participants and 18.9% (n= 18) of participants with FHO indicated that they have received medical advice about osteoporosis from a healthcare professional.

Table 2

Sources of Information Regarding Osteoporosis in Female College Students (N=352)

<table>
<thead>
<tr>
<th>Sources</th>
<th>(+) FHO % (n)</th>
<th>(-) FHO % (n)</th>
<th>Total % (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Friends and family</td>
<td>65.3 (62)</td>
<td>26.2 (127)</td>
<td>32.6 (189)</td>
</tr>
<tr>
<td>Magazines</td>
<td>24.2 (23)</td>
<td>18.2 (88)</td>
<td>19.2 (111)</td>
</tr>
<tr>
<td>Television</td>
<td>33.7 (32)</td>
<td>26.9 (130)</td>
<td>28 (162)</td>
</tr>
<tr>
<td>Social media</td>
<td>16.8 (16)</td>
<td>12.6 (61)</td>
<td>13.3 (77)</td>
</tr>
<tr>
<td>Doctor</td>
<td>22.1 (21)</td>
<td>15.5 (75)</td>
<td>16.6 (96)</td>
</tr>
<tr>
<td>Nurse</td>
<td>21.1 (20)</td>
<td>8.1 (39)</td>
<td>10.2 (59)</td>
</tr>
<tr>
<td>Dietitian</td>
<td>9.5 (9)</td>
<td>7.4 (36)</td>
<td>7.8 (45)</td>
</tr>
<tr>
<td>Physical therapist</td>
<td>11.6 (11)</td>
<td>2.1 (10)</td>
<td>3.6 (21)</td>
</tr>
<tr>
<td>Gym coach</td>
<td>3.2 (3)</td>
<td>2.7 (13)</td>
<td>2.8 (16)</td>
</tr>
<tr>
<td>Other</td>
<td>23.2 (22)</td>
<td>17.1 (83)</td>
<td>18.1 (105)</td>
</tr>
</tbody>
</table>

Abbreviations. (+) positive; (-) negative; FHO, family history of osteoporosis.
Knowledge Assessment: Osteoporosis, Risk Factors for Osteoporosis, Calcium Contents in Foods

In this section participants were asked about their general knowledge about osteoporosis and, modifiable and non-modifiable risk factors related to osteoporosis. In addition, participants were also assessed on their knowledge regarding calcium contents in certain food items.

**Overall knowledge score.** Overall, FHO group had significantly higher scores in knowledge assessment compared to participants who did not have FHO (P=0.001). Test results revealed that participants in this population scored between 58-65% in this section.

**General knowledge assessment.** Significant differences were seen among respondents with FHO in general knowledge assessment as compared to their counterparts (P= 0.001). The test results of general knowledge for osteoporosis is demonstrated in Table 3. An independent t-test found students with positive family history had significantly greater knowledge compared to the group without family history in eight out of 15 questions. Examples of questions that FHO group had higher scores include “osteoporosis is a hereditary disease”, “adequate calcium intake at childhood and adolescence can reduce your risk of osteoporosis”, and “physically active females have a higher chance of developing osteoporosis as compared to inactive females”, etc. Overall, students in both groups were more likely to score the highest among questions such as “What is osteoporosis”, “Adequate calcium intake at childhood and adolescence can reduce your risk of osteoporosis”, and “Adequate calcium intake during early adulthood...
(less than 30 years old) can help prevent osteoporosis”. Questions participants scored the lowest among included questions such as “Identify the activity/exercise that is beneficial for osteoporosis prevention”, “When do females build most of their bone mass?” and “Less than 25% of women develop osteoporosis in their lifetime”.

**Modifiable risk factor knowledge assessment.** Analysis of this section overall revealed there were significant differences between participants with FHO and their knowledge about modifiable risk factors of osteoporosis as compared to the group without FHO (P=0.001). Dummy variables in this section were excluded from analysis. Table 4 looks at differences in knowledge of modifiable and non-modifiable risk factors of osteoporosis between the two groups. In this population, female college students with FHO scored higher in four out of 17 questions such as family history, gender, vitamin D intake, etc. (P≤0.05).

Overall, participants in both groups were more likely to get risk factors such as calcium status, vitamin D status, physical activity, age, and family history correct as compared to other risk factors. Items that students in both groups scored lower than average on were sodium, use of diuretic medications, and protein consumption as risk factors of osteoporosis.

**Calcium content in food items knowledge assessment.** Results from this section showed that there were no significant differences between knowledge of calcium content in food items between the two groups (P=0.109). Table 5 compares differences in knowledge of calcium content in food items between the two groups. No statistical
difference was observed among most items (P≥0.05). Students with FHO were better in identifying canned salmon and cheese as high calcium content foods (P=0.002 and P=0.003) as compared to students without FHO who were better able to identify milk as a high calcium content food (P=0.045). Milk and cheese were also the highest scored food items in both groups. Furthermore, participants in both groups seemed to commonly misidentify items such as cottage cheese, soy milk and cream cheese as high calcium foods.

Table 3

*General Knowledge of Osteoporosis among Female College Students*

<table>
<thead>
<tr>
<th>Item</th>
<th>FHO status</th>
<th>X±SD</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>True or false</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Osteoporosis is a hereditary disease.</td>
<td>(+) FHO</td>
<td>0.86±0.35</td>
<td>0.003*</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.74±0.44</td>
<td></td>
</tr>
<tr>
<td>Osteoporosis cannot be prevented.</td>
<td>(+) FHO</td>
<td>0.88±0.32</td>
<td>0.290</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.85±0.36</td>
<td></td>
</tr>
<tr>
<td>Osteoporosis is an old woman’s disease.</td>
<td>(+) FHO</td>
<td>0.87±0.33</td>
<td>0.506</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.85±0.36</td>
<td></td>
</tr>
<tr>
<td>Adequate calcium intake at childhood and adolescence can reduce your</td>
<td>(+) FHO</td>
<td>0.96±0.20</td>
<td>0.027*</td>
</tr>
<tr>
<td>risk of osteoporosis.</td>
<td>(-) FHO</td>
<td>0.90±0.30</td>
<td></td>
</tr>
<tr>
<td>Adequate vitamin D intake can reduce your risk of osteoporosis.</td>
<td>(+) FHO</td>
<td>0.94±0.25</td>
<td>0.446</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.91±0.28</td>
<td></td>
</tr>
<tr>
<td>Adequate calcium intake during early adulthood (less than 30 years</td>
<td>(+) FHO</td>
<td>0.96±0.20</td>
<td>0.015*</td>
</tr>
<tr>
<td>old) can help prevent osteoporosis.</td>
<td>(-) FHO</td>
<td>0.90±0.31</td>
<td></td>
</tr>
<tr>
<td>Complications from osteoporosis can be deadly.</td>
<td>(+) FHO</td>
<td>0.83±0.38</td>
<td>0.122</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.76±0.43</td>
<td></td>
</tr>
</tbody>
</table>
Table 3 (continued)

**General Knowledge of Osteoporosis among Female College Students**

<table>
<thead>
<tr>
<th>Item</th>
<th>FHO status</th>
<th>( \bar{X} \pm SD )</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>True or false (continued)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physically active females have a higher chance of developing osteoporosis as compared to inactive females.</td>
<td>(+) FHO</td>
<td>0.87±0.33</td>
<td>0.014*</td>
</tr>
<tr>
<td>Bone loss speeds up after menopause.</td>
<td>(-) FHO</td>
<td>0.78±0.42</td>
<td></td>
</tr>
<tr>
<td>Less than 25% of women develop osteoporosis in their lifetime.</td>
<td>(+) FHO</td>
<td>0.89±0.31</td>
<td>0.108</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.84±0.37</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(+) FHO</td>
<td>0.71±0.46</td>
<td>0.013*</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.57±0.50</td>
<td></td>
</tr>
<tr>
<td>Multiple choice</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What is osteoporosis?</td>
<td>(+) FHO</td>
<td>0.96±0.20</td>
<td>0.048*</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.91±0.29</td>
<td></td>
</tr>
<tr>
<td>Which of the following is related to osteoporosis?</td>
<td>(+) FHO</td>
<td>0.79±0.41</td>
<td>0.044*</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.69±0.46</td>
<td></td>
</tr>
<tr>
<td>Identify which response best describes protective factors against osteoporosis.</td>
<td>(+) FHO</td>
<td>0.93±0.26</td>
<td>0.021*</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.85±0.35</td>
<td></td>
</tr>
<tr>
<td>Identify the activity/exercise that is beneficial for osteoporosis prevention.</td>
<td>(+) FHO</td>
<td>0.62±0.49</td>
<td>0.059</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.52±0.50</td>
<td></td>
</tr>
<tr>
<td>When do females build most of their bone mass?</td>
<td>(+) FHO</td>
<td>0.63±0.49</td>
<td>0.233</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.57±0.50</td>
<td></td>
</tr>
</tbody>
</table>

*Note: General knowledge score was scored by identification of the correct answer as a score of 1. Incorrect answers were scored as a score of 0.

*Abbreviations. (+) positive; (-) negative: FHO, family history of osteoporosis; SD, standard deviation; \( \bar{X} \), mean.

*Show t-test statistical significance, where statistical significance was set at \( p \leq 0.05 \).*
Table 4  

Knowledge of Modifiable and Non-Modifiable Risk Factors among Female College Students

<table>
<thead>
<tr>
<th>Item</th>
<th>FHO status</th>
<th>X ± SD</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Family history</td>
<td>(+) FHO</td>
<td>0.98±0.16</td>
<td>0.001*</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.89±0.32</td>
<td></td>
</tr>
<tr>
<td>Body weight</td>
<td>(+) FHO</td>
<td>0.91±0.29</td>
<td>0.987</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.91±0.28</td>
<td></td>
</tr>
<tr>
<td>Body frame</td>
<td>(+) FHO</td>
<td>0.77±0.42</td>
<td>0.454</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.73±0.44</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>(+) FHO</td>
<td>0.87±0.34</td>
<td>0.001*</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.73±0.44</td>
<td></td>
</tr>
<tr>
<td>Ethnicity</td>
<td>(+) FHO</td>
<td>0.74±0.44</td>
<td>0.001*</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.54±0.50</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>(+) FHO</td>
<td>0.92±0.27</td>
<td>0.501</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.90±0.30</td>
<td></td>
</tr>
<tr>
<td>Calcium status</td>
<td>(+) FHO</td>
<td>0.98±0.15</td>
<td>0.205</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.95±0.21</td>
<td></td>
</tr>
<tr>
<td>Smoking</td>
<td>(+) FHO</td>
<td>0.88±0.33</td>
<td>0.089</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.81±0.39</td>
<td></td>
</tr>
<tr>
<td>Alcohol</td>
<td>(+) FHO</td>
<td>0.82±0.38</td>
<td>0.052</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.72±0.45</td>
<td></td>
</tr>
<tr>
<td>Caffeine</td>
<td>(+) FHO</td>
<td>0.80±0.40</td>
<td>0.079</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.72±0.45</td>
<td></td>
</tr>
<tr>
<td>Sodium</td>
<td>(+) FHO</td>
<td>0.62±0.49</td>
<td>0.097</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.52±0.50</td>
<td></td>
</tr>
<tr>
<td>Vitamin D</td>
<td>(+) FHO</td>
<td>0.96±0.21</td>
<td>0.006*</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.88±0.32</td>
<td></td>
</tr>
<tr>
<td>Physical activity</td>
<td>(+) FHO</td>
<td>0.97±0.18</td>
<td>0.199</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.94±0.24</td>
<td></td>
</tr>
<tr>
<td>Protein consumption</td>
<td>(+) FHO</td>
<td>0.74±0.44</td>
<td>0.406</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.70±0.46</td>
<td></td>
</tr>
<tr>
<td>Use of steroid medication for asthma</td>
<td>(+) FHO</td>
<td>0.62±0.49</td>
<td>0.081</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.52±0.50</td>
<td></td>
</tr>
</tbody>
</table>
Table 4 (continued)

Knowledge of Modifiable and Non-Modifiable Risk Factors among Female College Students

<table>
<thead>
<tr>
<th>Item</th>
<th>FHO status</th>
<th>$\bar{X} \pm SD$</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of diuretic medication for high blood pressure</td>
<td>(+) FHO</td>
<td>0.59±0.50</td>
<td>0.010*</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.44±0.50</td>
<td></td>
</tr>
<tr>
<td>Hormone therapy after menopause</td>
<td>(+) FHO</td>
<td>0.69±0.46</td>
<td>0.060</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.59±0.49</td>
<td></td>
</tr>
</tbody>
</table>

Note: Modifiable and non-modifiable risk factors were scored by identification of the correct answer as a score of 1. Incorrect answers were scored as a score of 0. *Show t-test statistical significance, where statistical significance was set at p≤0.05.

Abbreviations. (+) positive; (-) negative: FHO, family history of osteoporosis; SD, standard deviation; $\bar{X}$, mean.

Table 5

Knowledge Test in Identifying Calcium Rich Food Items among Female College Students

<table>
<thead>
<tr>
<th>Item</th>
<th>FHO status</th>
<th>$\bar{X} \pm SD$</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>High calcium foods</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canned salmon with bone</td>
<td>(+) FHO</td>
<td>0.68±0.47</td>
<td>0.002*</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.50±0.50</td>
<td></td>
</tr>
<tr>
<td>Cheese</td>
<td>(+) FHO</td>
<td>0.98±0.15</td>
<td>0.003*</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.91±0.28</td>
<td></td>
</tr>
<tr>
<td>Milk</td>
<td>(+) FHO</td>
<td>0.96±0.20</td>
<td>0.045*</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.99±0.11</td>
<td></td>
</tr>
<tr>
<td>Peas</td>
<td>(+) FHO</td>
<td>0.25±0.44</td>
<td>0.650</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.23±0.42</td>
<td></td>
</tr>
<tr>
<td>Pinto beans</td>
<td>(+) FHO</td>
<td>0.42±0.50</td>
<td>0.381</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.37±0.48</td>
<td></td>
</tr>
<tr>
<td>Low calcium foods</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chocolate</td>
<td>(+) FHO</td>
<td>0.61±0.49</td>
<td>0.873</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.60±0.49</td>
<td></td>
</tr>
<tr>
<td>Cottage cheese</td>
<td>(+) FHO</td>
<td>0.08±0.27</td>
<td>0.484</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.06±0.24</td>
<td></td>
</tr>
</tbody>
</table>
Table 5 (continued)

Knowledge Test in Identifying Calcium Rich Food Items among Female College Students

<table>
<thead>
<tr>
<th>Item</th>
<th>FHO status</th>
<th>( \bar{X} \pm SD )</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low calcium foods (continued)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cream cheese</td>
<td>(+) FHO</td>
<td>0.21±0.41</td>
<td>0.323</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.16±0.37</td>
<td></td>
</tr>
<tr>
<td>Eggplant</td>
<td>(+) FHO</td>
<td>0.43±0.50</td>
<td>0.874</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.42±0.49</td>
<td></td>
</tr>
<tr>
<td>Mushrooms</td>
<td>(+) FHO</td>
<td>0.44±0.50</td>
<td>0.958</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.45±0.50</td>
<td></td>
</tr>
<tr>
<td>Potatoes</td>
<td>(+) FHO</td>
<td>0.63±0.49</td>
<td>0.061</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.52±0.50</td>
<td></td>
</tr>
<tr>
<td>Soy milk</td>
<td>(+) FHO</td>
<td>0.17±0.38</td>
<td>0.945</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.17±0.37</td>
<td></td>
</tr>
<tr>
<td>Tomatoes</td>
<td>(+) FHO</td>
<td>0.55±0.50</td>
<td>0.791</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>0.53±0.50</td>
<td></td>
</tr>
</tbody>
</table>

Note: Knowledge of calcium content of foods was scored by identification of each food item in relation to if it was “high in calcium”, or “low in calcium”. A score of “1” was assigned to food items that were correctly identified, whereas incorrect answers were scored as a score of “0”.

Abbreviations. (+) positive; (-) negative: FHO, family history of osteoporosis; SD, standard deviation; \( \bar{X} \), mean.

*Show t-test statistical significance, where statistical significance was set at \( p \leq 0.05 \).

Perceptions of Osteoporosis

Results from assessment of perceptions regarding osteoporosis are displayed in Table 6. On a modified 5-point Likert style scale, ranging from (1) ‘strongly disagree’ to (5) ‘strongly agree’ with (3) indicating ‘neither agree nor disagree’, participants with FHO scored higher in most perception questions of this section \( (P \leq 0.05) \) as compared to their counterparts. The only perception question that did not differ in the two groups was the general perception question “I believe osteoporosis is a more serious condition as compared to cardiovascular disease, diabetes, and cancer” \( (P=0.590) \). Participants in
both groups disagreed the most in this question as compared to any other perception question.

Table 6

Perceptions of Osteoporosis among Female College Students

<table>
<thead>
<tr>
<th>Item</th>
<th>FHO status</th>
<th>X ± SD</th>
<th>Total n</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I believe osteoporosis is a serious condition.</td>
<td>(+) FHO</td>
<td>4.47±0.62</td>
<td>89</td>
<td>0.001*</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>4.22±0.63</td>
<td>433</td>
<td></td>
</tr>
<tr>
<td>I believe osteoporosis is a more serious condition as compared to cardiovascular disease, diabetes, and cancer.</td>
<td>(+) FHO</td>
<td>2.59±0.74</td>
<td>88</td>
<td>0.590</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>2.54±0.79</td>
<td>432</td>
<td></td>
</tr>
<tr>
<td><strong>Risk</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I believe that family history of osteoporosis increases the risk of developing the disease.</td>
<td>(+) FHO</td>
<td>4.42±0.58</td>
<td>89</td>
<td>0.001*</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>4.10±0.64</td>
<td>431</td>
<td></td>
</tr>
<tr>
<td>I believe I am likely to develop osteoporosis in my lifetime.</td>
<td>(+) FHO</td>
<td>3.65±0.85</td>
<td>88</td>
<td>0.001*</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>2.86±0.91</td>
<td>432</td>
<td></td>
</tr>
<tr>
<td>I believe I have a greater risk of developing osteoporosis as compared to males that are my age.</td>
<td>(+) FHO</td>
<td>4.10±0.73</td>
<td>88</td>
<td>0.001*</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>3.69±0.87</td>
<td>431</td>
<td></td>
</tr>
<tr>
<td>I believe I have a greater risk of developing osteoporosis as compared to other females that are my age.</td>
<td>(+) FHO</td>
<td>3.45±0.92</td>
<td>88</td>
<td>0.001*</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>2.70±0.90</td>
<td>430</td>
<td></td>
</tr>
</tbody>
</table>

*Note. The mean is calculated from data from a 5-point modified Likert style scale where one equals ‘strongly disagree’ and five equals ‘strongly agree’.

*Abbreviations. (+) positive; (-) negative; FHO, family history of osteoporosis; SD, standard deviation; X, mean.

*Show t-test statistical significance, where statistical significance was set at p≤0.05.
Perception on Risk Reducing Behaviors against Osteoporosis

In this section participants were asked in a directive manner if they believe they actively practice risk reducing behaviors in order to prevent development of osteoporosis later in life.

Participant’s self-reported engagement in risk reducing activities and behaviors to prevent osteoporosis is highlighted in Table 7. On a modified 5-point Likert style scale, ranging from (1) ‘strongly disagree’ to (5) ‘strongly agree’ with (3) indicating ‘neither agree nor disagree’, (2) indicating ‘agree’ and (4) indicating ‘disagree’, students with FHO scored higher across all components of this section, except in decreasing their coffee, tea, soda or energy drink consumption and increasing their physical activity/weight bearing exercises to lower their risk of developing osteoporosis. In this sample population, the group of college students with FHO was significantly more likely to increase their calcium intake from foods and supplements and increase their vitamin D intake in order to reduce their risk of developing osteoporosis (P≤0.05). In addition, female college student without family history were significantly more likely to decrease their coffee, tea, soda, and/or energy drink consumption in order to lower their risk of developing osteoporosis (P<0.05).
Table 7

Perception on Risk Reducing Behaviors among Female College Students

<table>
<thead>
<tr>
<th>Item</th>
<th>FHO status</th>
<th>$\bar{X} \pm SD$</th>
<th>Total n</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Have you increased your calcium intake from food to lower your risk of developing osteoporosis?</td>
<td>(+) FHO</td>
<td>3.19±1.03</td>
<td>85</td>
<td>0.006*</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>2.87±0.95</td>
<td>415</td>
<td></td>
</tr>
<tr>
<td>Have you increased your calcium intake from supplements to lower your risk of developing osteoporosis?</td>
<td>(+) FHO</td>
<td>3.06±1.11</td>
<td>85</td>
<td>0.001*</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>2.56±0.97</td>
<td>409</td>
<td></td>
</tr>
<tr>
<td>Have you increased your sun exposure to lower your risk of developing osteoporosis?</td>
<td>(+) FHO</td>
<td>2.88±1.03</td>
<td>84</td>
<td>0.226</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>2.74±0.97</td>
<td>409</td>
<td></td>
</tr>
<tr>
<td>Have you increased your vitamin D intake to lower your risk of developing osteoporosis?</td>
<td>(+) FHO</td>
<td>3.21±1.09</td>
<td>84</td>
<td>0.007*</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>2.86±0.98</td>
<td>411</td>
<td></td>
</tr>
<tr>
<td>Have you decreased your coffee, tea, soda, or energy drink consumption to lower your risk of developing osteoporosis?</td>
<td>(+) FHO</td>
<td>2.45±0.88</td>
<td>84</td>
<td>0.047*</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>2.67±1.04</td>
<td>411</td>
<td></td>
</tr>
<tr>
<td>Have you decreased your alcohol consumption to lower your risk of developing osteoporosis?</td>
<td>(+) FHO</td>
<td>2.74±1.07</td>
<td>84</td>
<td>0.485</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>2.66±0.97</td>
<td>409</td>
<td></td>
</tr>
<tr>
<td>Have you increased your physical activity/weight bearing exercises to lower your risk of developing osteoporosis?</td>
<td>(+) FHO</td>
<td>2.90±1.05</td>
<td>84</td>
<td>0.953</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>2.90±1.00</td>
<td>410</td>
<td></td>
</tr>
<tr>
<td>Have you quit smoking to lower your risk of developing osteoporosis?</td>
<td>(+) FHO</td>
<td>3.00±1.10</td>
<td>84</td>
<td>0.085</td>
</tr>
<tr>
<td></td>
<td>(-) FHO</td>
<td>2.80±0.96</td>
<td>406</td>
<td></td>
</tr>
</tbody>
</table>

Note. The mean is calculated from data from a 5-point modified Likert style scale where one equals ‘strongly disagree’ and five equals ‘strongly agree’.

Abbreviations. (+) positive; (-) negative: FHO, family history of osteoporosis; SD, standard deviation; $\bar{X}$, mean.

*Show t-test statistical significance, where statistical significance was set at $p \leq 0.05$. 
Modifiable Risk Factor Assessment

In this section modifiable risk factors of osteoporosis were estimated in both groups with and without FHO through a series of questions related to current calcium intake, current involvement in sun exposure, alcohol consumption, smoking, exercise, and intake of coffee, soda, and energy drinks.

Current calcium intake in the population was estimated by utilizing Calcium Connection, a validated questionnaire from the Diary Council of California. Actual intake in mgs of calcium was calculated by multiplying the number of servings by either 300 mg or 100 mg depending on if they were excellent or good sources of calcium as indicated by the questionnaire, and summing up the total per participant. Average calcium intake among participants with family history and without family history (n=538) was 1164.9±1128.9 mg per day, and 1056.4±941.9 mg per day, respectively. No statistical significance was identified for the current calcium intake between the two groups (P≥0.05). In addition, among the sample 60.4% (n=325) consumed at least 750 mg of calcium per day, and 49.6% (n=267) consumed at 1,000 mg of calcium per day.

Dietary calcium sources consumed by participants in the past day were categorized into four sections: milk, dairy, non-dairy, and mixed dishes. Out of 563 participants, milk (38.7%; n=218) and dairy (86.7%; n=488) together were the top sources of calcium. Among non-dairy foods (n=300) dark leafy greens (58%; n=174) such as spinach, and kale were the food item consumed the most followed by broccoli or peas (35.3%; n=106) and beans (26.3%; n=79). Mixed dishes, were the least consumed
category (n=108) with macaroni & cheese (55.6%; n=60), followed by cream soup (25%; n=27) being the food item consumed most in this category.

There was no statistical significance difference in modifiable risk factor assessment between the two groups (P≥0.05), therefore analysis for the two groups were combined as displayed in Table 8. Most of the participants reported that they had sun exposure of two to three times a week during the months of March-October, and consumed less than two drinks of alcohol per day. However, about half of female students in the study reported that they consumed soda and about one third of all respondents were drinking more than five cups of soda per week.

Little more than half of the study population appeared to participate in weight bearing exercises such as walking, running, jogging, stair climbing or playing tennis three to five times a week. However, only a third of female students were engaged in resistance exercise and fewer participants were practicing combination of weight bearing and resistance exercise.

Table 8

*Modifiable Risk Factors of Osteoporosis in Female College Students*

<table>
<thead>
<tr>
<th>Modifiable Risks</th>
<th>(+) FHO</th>
<th>(-) FHO</th>
<th>Total % (n)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>Yes % (n)</td>
<td>No % (n)</td>
<td>Yes % (n)</td>
<td>No % (n)</td>
</tr>
<tr>
<td>Underweight (BMI &gt;18.5 kg/m²)</td>
<td>0.4 (2)</td>
<td>16.3 (92)</td>
<td>4.2 (24)</td>
<td>79.2 (448)</td>
</tr>
<tr>
<td>Sun Exposure (2-3x week Mar.-Oct.)</td>
<td>14.4 (83)</td>
<td>2.1 (12)</td>
<td>72.8 (421)</td>
<td>10.7 (62)</td>
</tr>
<tr>
<td>Smoking</td>
<td>1.6 (9)</td>
<td>14.9 (86)</td>
<td>4.7 (27)</td>
<td>78.8 (454)</td>
</tr>
</tbody>
</table>
### Table 8 (continued)

**Modifiable Risk Factors of Osteoporosis in Female College Students**

<table>
<thead>
<tr>
<th>Modifiable Risks</th>
<th>(+) FHOP</th>
<th></th>
<th>(-) FHOP</th>
<th></th>
<th>Total % (n)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes % (n)</td>
<td>No % (n)</td>
<td>Yes % (n)</td>
<td>No % (n)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Beverage Consumption</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alcohol</td>
<td>11.6 (58)</td>
<td>5.0 (25)</td>
<td>63.3 (318)</td>
<td>20.1 (101)</td>
<td>86.7% (502)</td>
<td>0.248</td>
</tr>
<tr>
<td>Two or more alcoholic drinks/day</td>
<td>2.0 (9)</td>
<td>13.6 (61)</td>
<td>14.7 (66)</td>
<td>69.8 (314)</td>
<td>77.7% (450)</td>
<td>0.352</td>
</tr>
<tr>
<td>Coffee</td>
<td>12.5 (72)</td>
<td>4.0 (23)</td>
<td>58.5 (337)</td>
<td>25.0 (144)</td>
<td>99.5% (576)</td>
<td>0.261</td>
</tr>
<tr>
<td>More than three cups of coffee/day</td>
<td>3.4 (14)</td>
<td>14.2 (58)</td>
<td>12.5 (51)</td>
<td>69.9 (286)</td>
<td>70.6% (409)</td>
<td>0.364</td>
</tr>
<tr>
<td>Soda</td>
<td>9.2 (53)</td>
<td>7.3 (42)</td>
<td>41.2 (237)</td>
<td>42.3 (243)</td>
<td>99.3% (575)</td>
<td>0.253</td>
</tr>
<tr>
<td>More than five cups of soda/week</td>
<td>7.6 (22)</td>
<td>10.8 (31)</td>
<td>24.3 (70)</td>
<td>57.3 (165)</td>
<td>49.7% (288)</td>
<td>0.098</td>
</tr>
<tr>
<td>Energy drinks</td>
<td>2.3 (13)</td>
<td>14.3 (82)</td>
<td>12.0 (69)</td>
<td>71.4 (409)</td>
<td>99.0% (573)</td>
<td>0.849</td>
</tr>
<tr>
<td>Two or more energy drinks/day</td>
<td>1.2 (1)</td>
<td>14.8 (12)</td>
<td>2.5 (2)</td>
<td>81.5 (66)</td>
<td>14.0% (81)</td>
<td>0.406</td>
</tr>
<tr>
<td><strong>Engagement in Exercises</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight bearing exercises</td>
<td>8.8 (50)</td>
<td>7.9 (45)</td>
<td>49.6 (283)</td>
<td>33.8 (193)</td>
<td>98.6% (571)</td>
<td>0.218</td>
</tr>
<tr>
<td>Resistance exercises</td>
<td>4.6 (26)</td>
<td>12.1 (69)</td>
<td>27.2 (155)</td>
<td>56.1 (320)</td>
<td>98.4% (570)</td>
<td>0.314</td>
</tr>
<tr>
<td>Combination of weight bearing and resistance exercise</td>
<td>2.8 (16)</td>
<td>13.9 (79)</td>
<td>20.8 (118)</td>
<td>62.4 (354)</td>
<td>97.9% (567)</td>
<td>0.088</td>
</tr>
</tbody>
</table>

*Abbreviations:* BMI Body Mass Index (calculated as kg/m²); SD, Standard Deviation

*Note.* For each modifiable risk factor percentage of (2x2) (+) FHOP and yes/no, and (-) FHOP and yes/no are equivalent to 100%.

*P*-value is ≤0.05.
Discussion

The primary purpose of this study was to assess knowledge and perception about osteoporosis and risk reducing behaviors of female college students with FHO in comparison with those without FHO. A secondary objective of this study was to compare modifiable risk factors of osteoporosis in the two groups. Study results indicated: 1) there were significant differences in general knowledge and risk factor knowledge about osteoporosis, however no difference in knowledge about calcium content in foods between two groups was observed; therefore Hypotheses 1 was only partially accepted; 2) there was significant differences in between risk perception in two groups; thus, Hypothesis 2 was accepted; 3) there was no significant difference between perception in risk reducing behaviors in this sample; hence, Hypothesis 3 was rejected; and 4) there was no significant difference in all modifiable risk factors between two groups; for that reason, Hypotheses 4 was rejected.

Characteristics of Study Population

In the current study, demographic data is representative with recent university data from spring 2016 that shows that collected revealed that: 1) 76.8% (n=22,256 students) are undergraduate students; 2) 23.2% (n=6,737 students) are graduate students; 3) majority of undergraduate students either junior’s (17.6%) or seniors (23.7%); and majority of students are between 20-21 years of age (32%) (Institutional Research, 2016; Start class, 2016). Similar distribution to the university data was also seen among
variables of mean age, and ethnicity, with students in both data sets predominantly identifying as being Caucasian (College data, 2015).

Data from the present study showed that 16.4% of the female participants had positive FHO, which is slightly lower than data from a previous, similar study (Robitalle et al., 2008). Discrepancies in data could be attributed to differences in defining FHO, smaller sample size and ethnic breakdown which is not representative of the demographics from the previous study.

**Sources of Information about Osteoporosis**

Over a half (60.7%) of the college students surveyed in the current study have been exposed to information about osteoporosis. Major sources for osteoporosis information in this study population appeared to be friends and family, television, and magazines followed by healthcare professionals. This result mirrors findings from a similar study that found that major sources of osteoporosis information were television, magazines, and healthcare services (Clark, & Lavielle, 2015).

Physician conveyed medical advice is an important factor that primes patients to act on health information and influences disease preventive behaviors. A previous study in the southeastern region of Missouri found that patients who received medical advice from their physician with supporting printed educational material in regards to smoking cessation were more than 50% more likely to have tried to quit smoking. In addition, this research found that patients who received supporting educational material were more likely to show educational material to a relative or friend (Kreuter, Chheda, & Bull,
In the current study, less than one fifth of female students (about 14% of all participants and 19% of participants with FHO) received medical advice regarding osteoporosis from a healthcare professional. To author’s knowledge there is no other study that evaluated if individuals received medical advice about osteoporosis. However, in a larger study evaluating the awareness, knowledge and perception of CVD among U.S. adult women, only 38% of reported to have a discussion about CVD with their physician (Mosca, Ferris, Fabunmi, & Robertson, 2004). This may reflect healthcare providers’ view on the severity of osteoporosis is less as compared to well-known, prevalent chronic diseases such as CVD, and the benefits of early preventive measures, or miscommunication between physicians and their patients. It is also possible that physician education has been conventionally geared toward curative medicine, and therefore they may not adequately trained in curative medicine practices (Puttapitakpong et al., 2014).

These findings collaboratively highlight the role of mass media in today’s world and the importance for the need of healthcare professionals to discuss this growing issue of osteoporosis with their patients.

**Knowledge Assessment**

Knowledge, as well as health perception has been long understood to be the cornerstone to facilitating behavior change (Wallace, 2002; Jalili, Nakaee, Askari, & Sharifi, 2006).
Overall knowledge of osteoporosis. Overall, respondents with FHO in the current study appeared to know more about osteoporosis compared to their counterparts. This difference could be attributed to their awareness about the disease and their awareness of their family history risk of developing the disease and therefore may be more proactive to seek information or knowledge related to osteoporosis. This finding is reflected results from various other studies evaluating chronic disease such as cardiovascular disease, and diabetes which has found that individuals with family history have higher overall knowledge, and knowledge of associated risk factors (Andsoy, Tastan, Iyigun, & Kopp, 2015; Sud, Roy, Emerson, & Hennessy, 2011; Baptiste-Roberts et al., 2007). However, Bird et al. (2011) reported that knowledge of breast cancer did not differ in women with family history in comparison to women without family history of breast cancer. Differences in the current study could be due to differences in geographic location of study, and sociodemographic characteristics of participants such as education level.

General knowledge of osteoporosis. In this knowledge section that assessed general aspects of osteoporosis, although participants with FHO demonstrated higher knowledge scores compared to their counterparts, the control group also scored high (above 0.75) on most questions. This finding is in agreement with previous research by Ford, Bass, & Keathley (2007) which found that college female students were more likely to identify what osteoporosis is, greatest bone loss occurs after menopause, and adequate lifetime calcium intake and regular exercise reduces osteoporosis, findings that are replicated in the current study. This result may be explained by higher education
level of this study population. In addition, approximately 40% of the participants took basic nutrition class in their freshman and sophomore years, which could have contributed to high knowledge level displayed in the current study.

However, notable in the present study, participants in both groups scored low on identification of the type of exercise that is beneficial for osteoporosis prevention, time frame of PBM acquisition, and general statistic of osteoporosis among women. These findings may indicate that participants know that exercise is an important factor of osteoporosis prevention, however do not understand that specific types of activities/exercises are more beneficial than others, which could significantly impact their ability to execute in these osteoporosis risk reducing behaviors. In addition, these results could also indicate that female college students underestimate the disease, and may be unaware that they are still able to achieve PBM during their young adult years, which can significantly reduce their risk of developing osteoporosis later in life. This finding is specifically troubling due to the reason that PBM is achieved up to the age of 30, and even an increase of one standard deviation of PBM can reduce fracture risk by 50% (Bonjour, Chevalley, Ferrari, & Rizzoli, 2009; Ediriweera de Silva et al., 2014). In this study approximately 90% of the participants in this study sample are under the age of 30 and still have potential to achieve a higher PBM. In addition, a majority of participants in this sample were Caucasian or Asian combined which places them at a higher risk of developing osteoporosis. Osteoporosis education, which has proven to increase participants knowledge in previous studies should be focused on filling these gaps of knowledge identified to in order for young adult female to understand the importance of
preventative behaviors through their college years, and the impact that it may have later in life (Sedlak, Doheny, & Jones, 2000; Ailinger, Braun, Lasus, & Whitt, 2005).

Modifiable risk factor knowledge of osteoporosis. Similar to the previous knowledge section, female students with FHO scored higher in modifiable risk factor knowledge test compared to the control group, though participants in both groups were more likely to answer high (0.75) on most questions in this section. High intakes of sodium and protein and diuretic and steroid uses were modifiable risk factors for osteoporosis that participants in both groups scored below 0.75.

This result indicates that female college students do not have a complete understanding about a role of dietary components and medications on adequate bone health, with the exception of calcium and vitamin D. This finding is concerning especially among the young female population which has been found to engage in unhealthy weight loss behaviors such as taking a diuretic to aid with weight loss. In fact, a study conducted by Davila et al. (2013) found that approximately 30% of their overweight or obese female college student populations were engaged in at least one healthy weight loss behavior, and that approximately 2% used a diuretic or smoked for weight management. In addition, previous research diuretics are one of the most commonly used drugs among female college athletes, with 12% of college female athletes reporting use diuretics (Karp, & Allena, 2004).

Furthermore, overconsumption of sodium in the U.S. population has been posed as a nutrient of concern by the Dietary Guidelines, and especially remains a nutrient of
concern among college students (Dietary Guidelines for Americans, 2016; Haberman, &
Luffey, 1998). In fact, previous research by Sen (2007) found that female college
students at Midwestern university consumed over double (mean= 3739 mg) of adequate
intake and above tolerable upper intake levels for Americans (Gropper, & Smith, 2013).
In terms of bone health, excessive sodium it is thought to negatively affect bone health by
increasing urinary calcium excretion (Gropper, & Smith, 2013; Angelo, 2012). Previous
research has indicated that for every 100 mmole (2299 mg) of sodium intake,
approximately 1 mmole (40 mg) of calcium is excreted and that women with lower
calcium intakes may be most vulnerable to the consequences of sodium-induced calciuria
affecting bone health (Nordin, Need, Morris, & Horowitz, 1993; Carbone, Bush, Barrow,
& Kang, 2003).

Furthermore, although students with FHO statistically significantly were able to
identified ethnicity as a non-modifiable risk factor as compared to students without FHO,
both groups still scored below 0.75 on this risk factor. Therefore, osteoporosis education
should encompass these modifiable risk factors to increase female college student’s
knowledge about the importance of nutrient components, medication usage to help them
lower their risk of developing the disease, in addition to the impact of pre-existing non-
modifiable risk factor education.

**Calcium knowledge of food items.** In terms of dietary calcium knowledge,
dissimilar to other knowledge sections, there was no significant (P≥0.05) difference in
two groups. However, overall participants in both groups were more likely to identify
milk and cheese as calcium-rich sources, but less likely to correctly identify calcium content of the other 11 items. It is possible that students may of misidentified soy milk as a calcium-rich source due to the reason they may have believed that it was fortified. However, findings in this section indicate that participants in the current investigation may not have sufficient knowledge about the calcium content of foods which is reflected by other studies which revealed that female participants had greater knowledge of calcium content of foods (Ford et al., 2007; Beaudoin, & Blum, 2005). This discrepancy highlights the need for osteoporosis education to focus on calcium content in foods to help students become more aware of how much calcium they are consuming.

**Perceptions of Osteoporosis**

College students with FHO in the study perceived osteoporosis as a serious condition more than their counterparts did, which may indicate that these individuals are more aware of the progression and detrimental nature of osteoporosis due to their family history. However, when participants were asked how they perceived the seriousness of osteoporosis as compared to other chronic diseases, there were not significant differences (P≥0.05) and responses were more likely to “disagree” in both groups. This finding is accordant with past research by Kasper, Peterson, & Allegrante (2001) which found that among 321 young adult college women the general perception was that osteoporosis was a serious condition however less serious as compared to heart disease, breast cancer, AIDS, and Alzheimer’s disease. These findings could be a result of the emphasis that is placed on other chronic diseases such as cardiovascular disease, diabetes, and cancer as
compared to information about osteoporosis by healthcare providers and media sources, and supports that osteoporosis is an underestimated disease.

In the U.S., CVD, diabetes, and cancer affects over 85 million, 29 million, and 14 million individuals, respectively, and are significant causes of mortality (approximately 18 million deaths a year) (Mozaffarian et al., 2016; American Diabetes Association, 2016; National Cancer Institute, n.d.). Osteoporosis, on the other hand, currently affects approximately ten million Americans with an additional 43 million who suffer from low bone density, cumulatively affecting more than half of the U.S. adult population (NOF, 2014). Severity of the consequences of osteoporosis are largely dependent on factors such as type of fracture, age, gender, and ethnicity and osteoporosis related deaths are due to comorbidities, but can also be due to the fracture directly or indirectly. In fact, research has demonstrated that mortality within the first year following a hip fracture ranges from 10-45%, and individuals who undergo surgical procedures for a hip fracture is at a higher risk of developing a postoperative complication such as infection or cardiovascular diseases, which are associated with a 90% increased mortality risk (Teng, Curtis, & Saag, 2008). Therefore, emphasis by healthcare providers and media sources should focus on osteoporosis to a similar degree as other chronic diseases such as cardiovascular disease and diabetes.

In addition, in the current investigation the group of students with FHO perceived their personal risk of developing osteoporosis to a greater degree as compared to their counterparts without family history. This finding is replicated in a similar study that was
conducted in Mexico City by Clark & Lavielle (2014) which found that participants with FHO were more concerned and perceived a greater likelihood of developing the disease as compared to participants without family history. Interestingly however, in the current study participants from both groups were more likely to perceive that osteoporosis is a serious disease, FHO increases risk of developing the disease, and they personally have a greater risk as compared to males in developing osteoporosis. This may suggest that as a population as a whole, these individuals may be more inclined to have a higher perception of the seriousness of osteoporosis, but not as high as other chronic diseases.

**Perception on Risk Reducing Behaviors**

FHO group in the current study believed they practiced in risk reducing behaviors against osteoporosis development compared to their counterparts: increasing calcium and vitamin D intakes. However, based on the results from the modifiable risk factor assessment, intakes of calcium and vitamin D were not different in the two groups. This may suggest that participants with FHO did not actively engage in preventative behaviors to reduce their osteoporosis risk as compared to the control group. In addition, this finding may also suggest that students with FHO overestimate their engagement in risk reducing behaviors to lower their risk of developing osteoporosis. This is in line with research conducted by Watkinson, Sluijs, Sutton, Marteau, & Griffin (2010), which examined self-reported physical activity versus objective physical activity among a sample in England. Results of the study showed that more than 60% of the participants were objectively categorized as being inactive, even though approximately half of these
individuals to their knowledge ranked themselves as being active and therefore were classified as being an “overestimator”. This is particularly distressing for participants in the present investigation who are at a higher risk of osteoporosis (with FHO), and may suggest that these individuals do not recognize they overestimate their engagement in risk reducing behaviors, and therefore may be unlikely to perceive a need to change and less receptive to health promoting strategies (Watkinson et al., 2010). To the author’s knowledge there is no other research that has assessed this relationship among individuals with FHO of osteoporosis, demonstrating the need for future research in this area.

**Modifiable Risk Factor Assessment**

In this sample, both groups appeared to have similar modifiable risks for osteoporosis, although students with FHO believed they increased dietary calcium, calcium supplementation and vitamin D intake in order to reduce their risk of developing osteoporosis.

Interestingly, knowledge test revealed that students with FHO had better knowledge of osteoporosis and its risk factors compared to their counterparts, which indicates that their knowledge was not translated into actions. This is accordant with the expanded health belief model that states that overall health motivation and self-efficacy are also significant contributing factors for individuals to partake in health promotion behaviors, and that knowledge although is a necessary component, itself is not adequate to facilitate behavior change (Wallace, 2002).
Participants in this study reported a mean calcium intake about 10% above dietary recommendation for their age group, 1,000 mg (Byrd-Bredbenner et al., 2013). High intake of calcium reported in this study may be due to individual’s tendency to overestimate the portion size of foods. This is in line with past research from the Academy of Nutrition and Dietetics that showed individuals are more likely to overestimate, as compared to underestimate portion sizes of foods, and that certain foods such as pasta, nuts, and mixed dishes were more likely to be overestimated as compared to others (Jonnalagadda, 1995). In addition, the present study utilized a validated food frequency questionnaire (FFQ) which has been found to overestimate normal intake by previous studies (Bingham et al., 1994; Kowalkowska et al., 2013; Crawford, Obarzanek, Morrison, & Sabry, 1994). For example, a study conducted by Crawford et al. (1994) found that a 5-day FFQ consistently overestimated energy as well as nutrients including carbohydrates, protein, fat, saturated fat, and cholesterol were consistently overestimated as compared to the participant’s actual intake and a 3-day food record. In fact, they found that absolute errors were between 20-33% through the FFQ method.

Although dietary calcium intake seemed to be adequate among this population, students with FHO did not consume dietary calcium more than their counterparts, a concerning finding due to their existing non-modifiable risk, family history. In addition, the recent Dietary Guidelines that were released earlier this year highlights underconsumption of the micronutrient due to low dairy consumption as a public health concern (Dietary Guidelines for Americans, 2016). It should be noted that in the present study, approximately 50% of the participants fell short of the RDA and approximately
80% of those who fell short of the RDA did not even meet 75% of the RDA, which is further concerning due to the reason that many of the participants may be partaking in risky behaviors, in addition, to their non-modifiable risk factors—being female, being of Caucasian descent, and FHO. A major limitation of this study was that calcium as well as vitamin D supplementation was not evaluated. Future studies should encompass this component in order to accurately assess intake of these essential vitamins to proper bone health.

Milk and dairy products were predominant sources of calcium in his study population. This is accordant with findings of calcium intake in the U.S. population which show that 73% of individuals report consuming milk and dairy making up approximately 40% of individuals total calcium intake (Hoy, & Goldman, 2014). In addition, this finding is comparable to findings from Douglas et al. (2010) which found that milk and dairy products such as cheese were the largest contributors for calcium among U.S. and Croatian college female students.

In this study population, both groups had similar modifiable risks for osteoporosis development: there were no significant differences in calcium intake, body weight, smoking, alcohol consumption, exercise and sun exposure between two groups (P≥0.05). This finding agreed to results from a similar study conducted by Robitalle et al. (2008) who used women with and without positive FHO. Their research also did not find any significant difference in modifiable risk factors such as body weight, smoking and intakes of alcohol and calcium between both groups. This finding in the present study suggests
that individuals with FHO did not practice risk reducing behaviors differently from the control group although they knew more about osteoporosis including modifiable risk factors.

As stated above, modifiable risk factors can have a significant impact on osteoporosis risk and bone density. For example, smoking can increase osteoporosis risk by 2.5 times as compared to non-smokers, regular exercise can reduce the risk of falls by 25%, coffee intake above four cups a day can reduce bone density by 2-4%, excessive alcohol consumption (> two drinks daily) can increase osteoporosis fracture risk by 40%, etc. (University of Pittsburgh Schools of the Health Sciences, 2016; Chan, Anderson, & Lau, 2003; Hallstrom et al., 2013; International Osteoporosis Foundation, 2015). Collaboratively, these findings are concerning for all of the participants in this study, as they are all female, but further troubling for the participants with FHO, a non-modifiable risk factor that has been identified as one of the most important risk factors of osteoporosis development (Iqbal, 2000). Therefore, it is absolutely critical that these individuals are proactive and take advantage of reducing their modifiable risk by engaging in osteoporosis preventative behaviors in order to prevent and/or delay the development of osteoporosis later in life.

Overall, female students in this study were more likely to get adequate sun exposure, five to fifteen minutes of sun exposure two to three times a week to the face, arms, back or legs, during the months of March-October (Cleveland Clinic, 2015). However, even with adequate sun exposure during this period time, considering the half-
life of storage form of vitamin D is nearly only three weeks (Johnson, 2010), it raises a concern that the participants in this study may not have sufficient vitamin D status by the winter months in which endogenous synthesis of vitamin D is nearly shut down and their bone health is negatively affected (Gropper, & Smith, 2013).

In addition, less than 40% of students in this sample reported engaging in resistance exercise and less than 25% of students in this study sample meet the recommendations set forth by the American College of Sports Medicine calls for daily engagement of 30-60 minutes in a combination of moderate to high intensity exercises including weight bearing, resistance exercises, and ones that involve jumping (Angelo, 2012). This finding is similar to a recent study by Ediriweera de Silva et al. (2014) found that less than 14% of the population engaged in recommended exercises for the given duration. In addition, in the U.S. only 20.8% of the population meets the federal physical activity guidelines for aerobic and muscle-strengthening activities. In fact, only 23.3% of women ages 18-24 meet the recommended guidelines, and this number plummets by more than 15% as age increases to 75 years or older. This number is substantially lower in females 18 years or older as they are less likely to meet the guidelines as compared to men as reported in the data from the 2014 National Health Survey (National Health Survey, 2015). This findings is specifically worrying among this population due to the reason that in addition as a modifiable risk factor for osteoporosis prevention, routine physical activity is considered an important preventative measure for many other chronic diseases such as CVD, diabetes, cancer, obesity and others (Warburton et al., 2006).

Analysis of this section in combination with general knowledge of osteoporosis section
revealed that participants lack knowledge related to what type activity/exercise is beneficial for osteoporosis prevention. Therefore, osteoporosis education in the future should encompass the importance resistance exercises and a combination of resistance and weight bearing exercises to raise student’s awareness for the prevention of developing the disease.

Beverage consumption among this sample indicated that participants in both groups were more likely to consume alcohol, coffee, and soda, however were predominately doing so in moderation, under the thresholds defined that could negatively affect their bone health. In this sample, less than 20% of the population indicated that they consume caffeinated drinks in excess: more than two alcoholic drinks a day, three or more cups of coffee a day, two or more energy drinks per a day, more than five cups of soda a week. Nevertheless, although beverage consumption of alcoholic and caffeinated beverage consumption in this population does not seem to be excessive, these small values that are observed among some participants consuming alcohol and caffeinated beverages should not be ignored as participants are likely to engage in more than one behavior that affects bone health in addition to any non-modifiable risk factor in addition to gender that they are already predisposed too, making their risk of developing osteoporosis relatively high when combined. Osteoporosis education should be geared in this aspect to reinforce the importance of abstaining from these drinks.
Limitations

As with any study, there are limitations that exist with this study. The first limitation is the validity and reliability of the questionnaire which utilized some questions that were developed by the researcher, and therefore validity and reliability studies on these questions have not been evaluated. Another limitation of this study was that a validated calcium food frequency questionnaire was used to determine dietary calcium intake among the sample, which could of lead to participants overestimating their intake. The third limitation of this study was that the data was self-reported, and therefore the validity of the responses cannot be determined. Another limitation was that there was no internet/website option for sources of information, which could affect the top sources of information about osteoporosis noted in this study. Finally, there were no questions regarding the participant’s calcium and vitamin D supplementation which is a risk reducing behavior that many individuals take.

Applications

In this current study, less than 20% of students with FHO received medical advice about osteoporosis prevention from a healthcare provider/physician, which places emphasis on the need for healthcare professionals to discuss this growing matter with their patients to an equal extent as other chronic diseases such as cardiovascular disease, and diabetes.

Gaps in knowledge about osteoporosis were observed in this population in matters regarding calcium content of foods, medication effects on health, time-frame of PBM
acquisition, and prevalence of osteoporosis among women. In addition, this study found that participants in this sample did not entirely understand dietary components and their effects to bone health through the knowledge assessment. This was even more concerning as high coffee and alcohol intake was seen among this population in addition to half of the participants reporting that they consume soda, and 30% of those students reporting consuming soda excessively. Another finding that was found in this current study was that students did not know the specific exercises/activities that were beneficial to osteoporosis prevention, and less than 25% of participants reported engaging in a combination of exercises which may have been due to lack in knowledge. Furthermore, in this study students with FHO did not increase their physical activity in order to reduce their risk of developing osteoporosis. Therefore, the findings in this study can be applied to educate college students, especially those with FHO, and are females, incorporating these components to raise awareness which can possibly enable engagement in risk reducing behaviors.

Furthermore, effort of students with FHO to reduce their risk of developing osteoporosis did not differ from that of participants without FHO. However, FHO group was more likely to overestimate that they were engaging in osteoporosis risk reducing measures, however were not doing so. This disparity between actual engagement and perceived engagement in risk reducing behaviors may be difficult to correct due to the reason that individuals perceive that they are already engaging in healthy behaviors for osteoporosis prevention. In this population, with technology available at your fingertips it may be beneficial for participants to track their intake and exercise on their phone.
through health apps such as Lose It, MyFitnessPal, or various other calorie and diet and physical activity trackers that are available to users. Use of these apps can provide users with a consistent way of monitoring their diet and activities; promoting self-management and support of a healthy lifestyle, and can make individuals realize what they are actually doing versus what they believe they are doing. In fact, current research shows that using this type of intervention is related to health behavior change and is valued by the young adult population, which is an important factor for continuing use/self-monitoring. However, limited research has been conducted in this area, highlighting the need for future research for this innovative intervention medium (Hebden, Cook, Ploeg, & Allman-Farinelli, 2012; Dennison, Morrison, Conway, & Yardley, 2013).

Conclusion

Although most of an individual’s osteoporosis risk is determined to be the effect of genetic predisposition and non-modifiable risk factors such as family history of osteoporosis, gender, ethnicity, etc. approximately 30% is attributed to environmental factors (Iqbal, 2000). Therefore, osteoporosis is largely preventable through appropriate diet and exercise behaviors, and attainment of PBM. College, typically a transition period for most young adults, poses a unique opportunity for young adults to enhance their modifiable risks and obtain their highest potential PBM until the age of 30. Hence, risk reducing measures should be taken during this life stage in order to prevent bone-related diseases such as osteoporosis later in life. The findings from this study show that female college students with FHO had better knowledge of osteoporosis, and its
modifiable risk factors, however lacked knowledge related to calcium content of food items and did not have a complete understanding about a role of dietary components and medications on adequate bone health. In addition, students with FHO had higher general and risk perception of osteoporosis, and believed that they increased their calcium intake from foods and supplements, and vitamin D intake to lower their risk of developing osteoporosis. However, were there were no differences in modifiable risks such as dietary calcium intake, physical activity, body weight, sun exposure, smoking, alcohol, soda, coffee, and energy drink consumption between the two groups. Overall, the current study highlighted the importance of healthcare professionals to discuss osteoporosis prevention with their patients, especially those at with FHO, and gaps in knowledge that need to be filled through osteoporosis education. Furthermore, the findings from this study show the difference in actual engagement versus perceived engagement which individuals need to be aware of in order to take measures to avoid this discrepancy and reduce their risk of developing osteoporosis.
APPENDICES
APPENDIX A

CONSENT FORM
Appendix A

Consent Form

Knowledge, Perception and Risk Reducing Behaviors among Female College Students with Family History of Osteoporosis

Thank you for your interest in completing this survey! Before participating in this study, please read the consent form located below and click the button “I agree” if you decide to freely consent to participate in this study.

CONSENT FORM

This study will be conducted by Professor Eun-Jeong Ha, an associate professor of Nutrition and Dietetics, and Krishna Patel, a dietetic intern & graduate student in Nutrition and Dietetics. The study will be approved by the Kent State University Institutional Review Board, and will not involve deception of any kind. Participation in the study will be completely anonymous and confidential. In no circumstance will responses from individual participants be disclosed.

Participating in this survey is entirely optional. If at any time you feel uncomfortable or wish to stop, you may do so. Refusal to participate, or stopping at anytime throughout the survey does not hold any penalty. Participants will be given the option to enter into a random drawing for four $25 Amazon gift cards. Contact information will be obtained for the gift card drawing and will not in any form be linked to any responses from the survey.

The purpose of this study is to assess differences in knowledge and perception about osteoporosis and risk reducing behaviors of those with family history of osteoporosis in comparison with those without family history of osteoporosis in female college students. A scare amount of information is known about knowledge, perception, and disease preventative behavior among the female college student population, especially those with family history of osteoporosis. The data collected from this web-based questionnaire will be beneficial for increasing awareness and aiming interventions to increase knowledge and likelihood of developing this detrimental disease. In addition,
data collected from this study can be utilized to further research studies in this area, and can be used in future healthcare settings.

If you are curious and would like further information regarding this study, please feel free to contact the principal investigator, Professor Eun-Jeong Ha, at (330) 672-2701; or Krishna Patel at kpatel14@kent.edu; or the Kent State University Institutional Review Board, at (330) 672-2704.

_Completion of the survey constitutes consent to participate. If you freely consent to participate in this survey, understand the statements above, and are of 18 years of age or older, click on the “I agree” button to begin._

I Agree  I Do Not Agree
APPENDIX B
SURVEY QUESTIONNAIRE
Appendix B
Survey Questionnaire

General Demographics

Q1 How old are you?

If How old are you? Is Less Than 18, Then Skip To End of Survey

Q2 Please indicate your sex?
- Male
- Female
- Neither

If Male Is Selected, Then Skip To End of Survey If Neither Is Selected, Then Skip To End of Survey

Q3 What is your ethnicity?
- Caucasian
- Asian
- Hispanic
- African American
- Native American
- Other (please indicate): ____________________

Q3 What is your ethnicity?
- Caucasian
- Asian
- Hispanic
- African American
- Native American
- Other (please indicate): ____________________
Q4 How tall are you? I am _____ feet and _______ inches tall (fill in the blanks)
   Feet _________
   Inches ________

Q5 What is your weight in pounds?

Q6 What is your class ranking?
   ○ Freshman
   ○ Sophomore
   ○ Junior
   ○ Senior
   ○ Graduate student

Q7 Have you ever taken a college nutrition course?
   ○ Yes
   ○ No

General Questions

Q8 Have you ever been informed that you are at risk for developing osteoporosis by a healthcare professional?
   ○ Yes
   ○ No

Q9 Have you ever received any medical advice from a healthcare professional about osteoporosis?
   ○ Yes
   ○ No
Q10 Have you ever been exposed to information about osteoporosis?

☐ Yes
☐ No

Answer If Have you ever been exposed to information about osteoporosis? Yes Is Selected

Q10b Have you received information about osteoporosis from any of the sources below? (Check all that apply)

☐ Family and/or friends
☐ Magazines
☐ Television
☐ Social media
☐ Nurse
☐ Doctor
☐ Physical therapist
☐ Dietitian
☐ Gym coach
☐ Other ____________________

Risk Factors: History of previous fractures and family history of osteoporosis

Q11 Does anyone in your family (defined as parents, siblings, grandparents, and aunts) have osteoporosis?

☐ Yes
☐ No
☐ Do not know

Q12 Does anyone in your family have a history of fragility fractures (fractures resulting from a fall at standing height or less)?

☐ Yes
☐ No
☐ Do not know

Modifiable Risk Factors
Q13 During months of March-October (spring to fall) do you get sun exposure 2-3 times a week? Sun exposure defined as 5 minutes or more in the sun directly exposing body parts such as legs, arms, face or torso.

- Yes
- No

If No Is Selected, Then Skip to do you drink alcohol?

Q14 Do you drink alcohol?

- Yes
- No

If No Is Selected, Then Skip to do you currently smoke daily or have ...

Q14b Do you drink 2 or more drinks of alcohol in a day? 1 drink = 1 shot of liquor, 1 bottle of beer, and/or ½-⅔ cup of wine.

- Yes
- No

Q15 Do you currently smoke daily or have you smoked daily in the past?

- Yes, I currently smoke
- Yes, I have smoked in the past, but do not currently smoke
- No, I have never smoked

Q16 Do you drink coffee?

- Yes
- No

If No Is Selected, Then Skip to do you drink soda?
Q16b Do you drink more than 3 cups (24 fluid ounces total) of coffee per a day? 8 fluid ounces is one cup; a Starbucks Venti is equivalent to 2.5 cups)

- Yes
- No

Q17 Do you drink soda?

- Yes
- No

If No Is Selected, Then Skip to do you drink energy drinks?

Q17b Do you drink more than 5 soda drinks per a week? Soda is defined as any cola that is not a lemon-lime drink, or ginger ale. A standard drink is 8 fluid ounces; A can of soda is a drink equivalent to 1.5 drinks; A standard plastic bottle is equivalent to 2.5 drinks.

- Yes
- No

Q18 Do you drink energy drinks?

- Yes
- No

If No Is Selected, Then Skip to do you participate in weight bearing ...

Q18b Do you drink two or more energy drinks per a day? A standard energy drink is 16 fluid ounces; Note a big can of Monster (24 fluid ounces) is equivalent to 1.5 energy drinks

- Yes
- No

Q19 Do you participate in weight bearing exercises such as walking, running, jogging, stair climbing or playing tennis 3-5 times a week?

- Yes
- No
Q20 Do you participate in activities that involve resistance exercises such as weight lifting 2-3 times a week?

☐ Yes
☐ No

Q21 Do you participate in a combination of activities including weight bearing endurance activities, activities involving jumping such as jump roping, and resistance exercises that target major muscle groups at least 30 minutes per a day? Swimming is a low-impact exercise and does not qualify as a weight bearing endurance activity or resistance exercise.

☐ Yes
☐ No

**Calcium Questionnaire**

Q22 How many 1 cup (8 ounce) servings of the following did you have yesterday?

_____ Milk: plain or flavored
_____ Yogurt: plain or flavored
_____ Milkshakes, hot chocolate, coffee drinks such as lattes
_____ Desserts with milk: puddings, custards
_____ Calcium-fortified soy, rice or almond beverage

Q23 How many 1.5 ounce or 1/3 cup shredded servings of the following did you have yesterday?

_____ Hard cheese
_____ Low-fat cheese
_____ Mozzarella
_____ Processed cheese (2 ounces per serving)
Q24 How many servings (1 large piece) of the following did you have yesterday?

_____ Lasagna
_____ Enchilada
_____ Sardines with bones (6 pieces; approximately 1 can)
_____ Tofu processed with calcium (4 ounces)

Q25 How many 1/2 cup servings of the following did you have yesterday?

_____ Cottage cheese
_____ Bok Choy
_____ Ice cream, frozen yogurt

Q26 How many 1 cup servings of the following did you have yesterday?

_____ Beans: dried, refried, baked
_____ Cream soup
_____ Macaroni & cheese
_____ Broccoli or peas
_____ Dark leafy greens: spinach, kale, mustard greens, turnip greens

Q27 How many 1/4 cup servings of the following did you have yesterday?

_____ Almonds (23 almonds)
_____ Sour cream

Q28 How many servings of the following did you have yesterday?

_____ Corn tortillas (2 tortillas equal 1 serving)
_____ Figs (5 figs equal 1 serving)
_____ Canned fish such as salmon or mackerel with bones (2 ounces equals 1 serving)

Knowledge Questions
Q29 What is osteoporosis?

- a rare disease that affects your muscles
- a chronic disease that affects your bones
- a rare disease that affects your brain
- a chronic disease that affects your heart valves

Q30 Osteoporosis is a hereditary disease.

- True
- False

Q31 Osteoporosis cannot be prevented.

- True
- False

Q32 Osteoporosis is an old woman's disease.

- True
- False

Q33 Adequate calcium intake at a childhood and adolescence can reduce your risk of osteoporosis.

- True
- False

Q34 Adequate vitamin D intake can reduce your risk of osteoporosis.

- True
- False
Q35 Adequate calcium intake during early adulthood (less than 30 years old) can help prevent osteoporosis.

- True
- False
Q36 Please indicate if each of the factors below affect bone health.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Affects bone health</th>
<th>Does not affect bone health</th>
<th>I do not know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Family history of osteoporosis</td>
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<td>○</td>
<td>○</td>
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<tr>
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<tr>
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<td>○</td>
<td>○</td>
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</tr>
<tr>
<td>Smoking</td>
<td>○</td>
<td>○</td>
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</tr>
<tr>
<td>Alcohol</td>
<td>○</td>
<td>○</td>
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</tr>
<tr>
<td>Caffeine</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Sodium</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Vitamin D</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Potassium</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Water</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Physical activity</td>
<td>○</td>
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</tr>
<tr>
<td>Ethnicity</td>
<td>○</td>
<td>○</td>
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</tr>
<tr>
<td>Fat consumption</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Carbohydrates consumption</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Protein consumption</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Use of steroid medication for asthma</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Use of diuretic medication for high blood pressure</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Use of cholesterol lowering medication</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Hormone therapy after menopause</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>
Q37 Please indicate if each food item below is high in calcium.

<table>
<thead>
<tr>
<th>Food Item</th>
<th>High in calcium</th>
<th>Low in calcium</th>
<th>I do not know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cottage cheese</td>
<td>○</td>
<td>○</td>
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</tr>
<tr>
<td>Cream cheese</td>
<td>○</td>
<td>○</td>
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</tr>
<tr>
<td>Chocolate</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Milk</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Cheese</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Canned salmon with bone</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Pinto beans</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Peas</td>
<td>○</td>
<td>○</td>
<td>○</td>
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<tr>
<td>Potatoes</td>
<td>○</td>
<td>○</td>
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<tr>
<td>Tomatoes</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Eggplant</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Mushrooms</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Soy milk</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

Q38 Which of the following is related to osteoporosis?

- Metabolic syndrome
- Fragility fracture
- Clinical depression
- Calcification of arteries
- Arthritis

Q39 Identify which response best describe protective factors against osteoporosis.

- Eating meats with a good amount of protein, taking aspirin, and getting enough sunlight
- Exercising, getting enough calcium, and getting adequate sunlight
- Not having any children, being older, and starting menopause early
- A diet with high in protein, aging, and being a female
Q40 Identify the activity/exercise that is beneficial for osteoporosis prevention.

- Sit ups
- Swimming
- Weight lifting
- Bowling

Q41 Complications from osteoporosis can be deadly.

- True
- False

Q42 When do females build most of their bone mass?

- During childhood to early adulthood
- During early adulthood to mid-thirties
- During mid-thirties to fifties
- After menopause
- Bone mass builds equally though all life stages

Q43 Physically active females have a higher chance of developing osteoporosis as compared to inactive females?

- True
- False

Q44 Bone loss speeds up after menopause.

- True
- False

Q45 Less than 25% of women develop osteoporosis in their lifetime.

- True
- False
General Perception Questions

Q46 I believe osteoporosis is a serious condition

- Strongly agree
- Agree
- Neither Agree nor Disagree
- Disagree
- Strongly Disagree

Q47 I believe osteoporosis is a more serious condition compared to cardiovascular disease, diabetes, and cancer.

- Strongly agree
- Agree
- Neither Agree nor Disagree
- Disagree
- Strongly Disagree

Risk Perception

Q48 I believe that a family history of osteoporosis increases the risk of developing the disease.

- Strongly agree
- Agree
- Neither Agree nor Disagree
- Disagree
- Strongly Disagree

Q49 I believe I am likely to develop osteoporosis in your lifetime.

- Strongly agree
- Agree
- Neither Agree nor Disagree
- Disagree
- Strongly Disagree
Q50 I believe I have a greater risk of developing osteoporosis as compared to males that are my age.

- Strongly agree
- Agree
- Neither Agree nor Disagree
- Disagree
- Strongly Disagree

Q51 I believe I have a greater risk of developing osteoporosis as compared to other females that are my age.

- Strongly agree
- Agree
- Neither Agree nor Disagree
- Disagree
- Strongly Disagree

Preventative Behavior

Q52 The following questions are related only to osteoporosis preventative measures

Q53 Have you made any lifestyle changes to prevent yourself from getting osteoporosis such as changing your diet, exercising more, and/or stop smoking?

- Yes
- No
- I do not know
- Refused
Q54 Have you increased your calcium intake from food to lower your risk of developing osteoporosis?

- Strongly agree
- Agree
- Neither Agree nor Disagree
- Disagree
- Strongly Disagree

Q55 Have you increased your calcium intake from supplements to lower your risk of developing osteoporosis?

- Strongly agree
- Agree
- Neither Agree nor Disagree
- Disagree
- Strongly Disagree

Q56 Have you increased your sun exposure to lower your risk of developing osteoporosis?

- Strongly agree
- Agree
- Neither Agree nor Disagree
- Disagree
- Strongly Disagree

Q57 Have you increased your vitamin D intake to lower your risks of developing osteoporosis?

- Strongly agree
- Agree
- Neither Agree nor Disagree
- Disagree
- Strongly Disagree
Q58 Have you decreased your coffee, tea, soda, or energy drink consumption to lower your risk of developing osteoporosis?

- Strongly agree
- Agree
- Neither Agree nor Disagree
- Disagree
- Strongly Disagree

Q59 Have you decreased your alcohol consumption to lower your risk of developing osteoporosis?

- Strongly agree
- Agree
- Neither Agree nor Disagree
- Disagree
- Strongly Disagree

Q60 Have you increased your physical activity/weight bearing exercise to lower your risk of developing osteoporosis?

- Strongly agree
- Agree
- Neither Agree nor Disagree
- Disagree
- Strongly Disagree

Q61 Have you quit smoking to lower your risk of developing osteoporosis?

- Strongly agree
- Agree
- Neither Agree nor Disagree
- Disagree
- Strongly Disagree
Q232 Would you like to be considered for the incentive for the completion of this survey?

☐ Yes
☐ No
REFERENCES
REFERENCES


Anding, J. D., Suminski, R. R., & Boss, L. (2001). Dietary intake, body mass index, exercise, and alcohol: Are college women following dietary guidelines for


College data (2015). *College profile: Kent State University.* Retrieved from
http://www.collegedata.com/cs/data/college/college_pg06_tmpl.jhtml?schoolId=8

doi:10.1016/j.berh.2006.04.004


Sen, R. (2007). Nutrient intake in college students in a midwestern regional university compared to the recommended dietary guidelines (Master’s thesis). Retrieved from Master’s Theses and Doctoral Dissertations by DigitalCommons @EMU.


Start class (2016). Kent State University at Kent. Retrieved from
http://colleges.startclass.com/l/3293/Kent-State-University-at-Kent

(2nd ed.). St. Louis, MO: Saunder Elsevier.


history of cardiovascular disease, knowledge of cardiovascular disease risk factors
doi:10.1071/PY12010

doi:10.1016/j.amepre.2014.06.013

calcium or calcium in combination with vitamin D supplementation to prevent
fractures and bone loss in people aged 50 years and older: A meta-analysis. The
Lancet, 370, 657-666. doi:10.1016/S0140-6736(07)61342-7

the link causal, and is it modifiable? Clinical and Experimental Rheumatology,


