COMPARISON OF DIETARY CALCIUM INTAKE
OF COLLEGE-AGED INDIVIDUALS WITH
LACTOSE INTOLERANCE TO THOSE WITHOUT

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The purpose of this study was to evaluate the differences in dietary calcium and milk and dairy product intake of those with lactose intolerance compared to those without in college students. Participants of this study included 1,724 college students from Kent State University between the ages of 18 to 30 years old. A total of 193 participants identified as being lactose intolerant. Statistical methods included descriptive statistics, a one-way ANOVA, and post-hoc analysis. Students with lactose intolerance consumed less milk and dairy products \((p < 0.001)\) and did not reach the daily recommendations for calcium. Individuals that were doctor-diagnosed consumed significantly less overall daily calcium compared to those without \((p < 0.05)\). Both of the lactose intolerant groups consumed significantly more non-dairy and supplemental calcium sources \((p < 0.05)\). There were no significant differences between calcium intake and those that were self-diagnosed or doctor-diagnosed with lactose intolerance. The results of this study provide framework for future studies and the re-examination of nutrition intervention for those with lactose intolerance. There is concern regarding the ineffectiveness of nutrition intervention for those with lactose intolerance. The results of this study can be used by registered dietitians (RD) for nutrition intervention to prevent inadequate calcium intake in college-aged individuals with lactose intolerance. Increasing the presence of RDs in
the political, community, and clinical settings can allow individualized counseling to aid in the prevention of osteoporosis, a major public health concern.
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CHAPTER I
INTRODUCTION

College is a time for change and is often where lifelong habits are shaped (Ha & Caine-Bish, 2009). The college-era has markedly been a period of poor nutritional intake and unhealthy lifestyle habits including excessive intake of saturated fats, cholesterol, and sodium, along with inadequate intake of fiber, iron, folate, and calcium (Ha & Caine-Bish, 2009; Haberman & Luffey, 1998). It has been estimated that between the ages of 19 to 30 years, only 53% of males and 21% of females in the United States meet the daily recommendation of calcium (1000-1300 mg; Larson et al., 2009). Overall, college students are at risk for inadequate calcium consumption and furthermore, those with lactose intolerance must search for alternative sources of calcium such as fortified foods and supplements (Carroccio, Montalto, Cavera, & Notartbatolo, 1998; Ha & Caine-Bish, 2009; Haberman & Luffey, 1998; Larson et al., 2009). Importantly, the college years typically fall on the end of the peak bone development window where there is still time to improve skeletal mass, and prevent osteoporosis later in life, through adequate calcium intake.

Ninety-nine percent of calcium is utilized as the primary constituent for bone and teeth formation, providing both their structure and hardness (J. Brown, 2008; National Institutes of Health: Office of Dietary Supplements, 2012). Higher calcium intake causes increased calcium retention and decreased bone remodeling thus preventing osteoporosis (Heaney, 2000). The Dietary Reference Intakes (DRIs) calcium recommends 1300 milligrams (mg) between the ages of nine to 18 per day for both males and females.
Adolescence is an important time where 98% of skeletal development occurs and the remaining 2% occurs up to age 30; this is known as the window for peak bone mass development (J. Brown, 2008; Larson et al., 2009; U.S. Department of Agriculture [USDA], 2012). Therefore, with sufficient intake of calcium, young adults can achieve peak bone mass, which is an important determinant of osteoporotic fracture risk later in life. However, dietary calcium intake has been noted to decrease with age. A longitudinal study discovered that average absolute- and average density-calcium intakes decreased in the transition from middle adolescence to young adulthood and were lower than the recommended Adequate Intake (AI) levels; on average, females consumed 153 mg and males 194 mg less during the transitional stage from adolescence to young adulthood (Larson et al., 2009).

There are various sources of calcium including foods naturally rich in calcium, fortified foods and beverages, and supplements. However, not all sources of calcium are equal and each source has varying degrees of bioavailability. Though some plant sources have a high calcium content, generally, plant sources are low in bioavailability (Weaver, Proulx, & Heaney, 1999). Therefore, dairy products are one of the best sources of calcium in that it offers high bioavailability along with other important nutrients, such as phosphorus, potassium, fortified vitamin D, and many other nutrients (Heaney, 2000; Nicklas, 2003). In the American diet, 75% of dietary calcium is consumed through dairy products (Swagerty, Walling, & Klein, 2002).

However, those with lactose intolerance tend to avoid dairy products to evade adverse symptoms (Swagerty et al., 2002; Vesa, Marteau, & Korpela, 2000). Lactose
intolerance is a condition characterized by the inability or difficulty to digest the disaccharide lactose, notably found in dairy products, due to diminished activity of the enzyme lactase-phlorizin hydrolase, more commonly known as “lactase” (Swagerty et al., 2002). Lactose intolerance is widespread, affecting an estimated 30 to 50 million Americans with a greater prevalence in certain ethnicities (Cleveland Clinic, 2011; Heyman, 2006; Swagerty et al., 2002; Suarez et al., 1995; Vesa et al., 2000). Consequences of insufficient lactase activity include the following: abdominal pain, bloating, flatulence, loose stools, and borborygmi, or gurgling, due to fluid and gas accumulation in the intestines following the ingestion of lactose-containing foods (Swagerty et al., 2002; Vesa et al., 2000). These symptoms often lead to those with lactose intolerance to avoid dairy products. One research study found that those with lactose intolerance consumed around 320 mg of milk per day which was significantly less than non-lactose intolerant subjects; posing a risk for inadequate calcium intake (Carroccio et al., 1998). As a result, college students with lactose intolerance must seek alternative sources of calcium in order to prevent an even greater risk for inadequate calcium and future osteoporosis risk.

Statement of the Problem

Calcium is essential to the human body and is primarily utilized in skeletal development. Inadequate calcium intake can lead to a variety of conditions, most commonly osteoporosis, or decreased bone mass, which can result in debilitating bone fractures and breaks. To prevent osteoporosis, adequate calcium intake must occur throughout a person’s lifetime, particularly during early adulthood (J. Brown, 2008;
Traditionally, peak bone mass is developed within the first two decades of life; making the traditional college-aged era a critical time for skeletal development (Nicklas, 2003). College-aged students are not meeting the recommended daily requirements of calcium for their age group. A longitudinal study found that females consumed, on average, approximately 860 mg and males consumed 1052 mg of calcium daily during young adulthood, both below the Daily Recommended Intakes of calcium (Ha & Caine-Bish, 2009; Haberman & Luffey, 1998; Larson et al., 2009). The major avenue of calcium intake for Americans is through milk and dairy products (Swagerty et al., 2002). However, individuals with lactose intolerance often avoid dairy products due to their inability to metabolize and digest the sugar lactose. Studies have demonstrated that those with lactose intolerance not only have lower levels of dairy consumption, but also have a significant reduction in calcium intake compared to subjects without lactose-digestion difficulties (Carroccio et al., 1998; Jarvis & Miller, 2002). A study completed by Kull et al. (2009) compared lactose intolerance, milk consumption, and bone mineral density in men and women between the ages of 25 and 70 years old. In this study they found that those with lactose intolerance not only had a 38% decrease in milk consumption, but also had an increase in bone turnover and increased fracture risk. College students with lactose intolerance tend to avoid an important source of dietary calcium requiring them to search for alternative dietary sources of calcium. In addition, previous studies have demonstrated that college students do not know about the current recommendations for calcium, nor are they aware of calcium content in dairy and non-dairy sources (Nicklas, 2003). Despite being an era where additional bone
development can occur, the literature is lacking research on calcium intake of the college-aged population with lactose intolerance compared to those without.

**Purpose Statement**

The purpose of this study is to evaluate the differences in dietary calcium, milk, and dairy product intake of those with lactose intolerance compared to those without in college students.

**Hypotheses**

It is hypothesized that individuals with lactose intolerance compared to those without will consume a different amount of calcium.

It is hypothesized that individuals with lactose intolerance will consume a different amount of milk and dairy products compared to those without.

**Definition of Terms**

*College-aged student:* Individuals between the ages of 18 to 30 are considered to be “college-aged.”

*Dairy products:* Food products produced from milk such as butter and cheese.

*Graduate students:* These students are obtaining advanced education, such as their master’s and doctoral degrees.

*Lactose intolerance:* A condition characterized by the inability or difficulty to digest lactose (lactose malabsorption) due to the diminished activity of the enzyme lactase with the presence of adverse side effects including abdominal pain and distention, flatulence, loose stools, and stomach gurgling.
Milk: A white liquid produced from mammals, particularly cows, and is a major source of calcium in the human diet.

Undergraduate students: These students are obtaining their bachelor’s degree that typically takes four years.
CHAPTER II
REVIEW OF LITERATURE

Lactose Intolerance

Overview

Lactose is a disaccharide that is made up of the two monosaccharide: glucose and galactose and is the primary carbohydrate that is found in milk and dairy products (Heyman, 2006; Nelms, Sucher, Lacey, & Roth, 2007). Absorption of lactose requires the enzyme called lactase in the brush border of the small intestine, with the highest concentration in mid-jejunum, and splits the link between the two monosaccharides (Heyman, 2006; Lomer, Parkes, & Sanderson, 2008). Lactose intolerance is a condition where there is an inability or difficulty to digest the disaccharide lactose as a result of the diminished activity of the enzyme lactase (Heyman, 2006; Swagerty et al., 2002).

The lactase enzyme is located on the tips of the villi (Heyman, 2006). Most of the lactase activity comes from lactase-phlorizin hydrolase, which is a beta-galactosidase, within the intestinal mucosa (Heyman, 2006; Lomer et al., 2008; Vesa et al., 2000). In normal lactose absorption, following the hydrolysis of lactose into glucose and galactose, these monosaccharides are absorbed into the blood stream through intestinal enterocytes. The glucose that is absorbed will be used primarily as an energy source, whereas galactose will be used as a glycolipid and glycoprotein component (Lomer et al., 2008). Without adequate lactase activity, however, lactose remains unabsorbed which results in intestinal discomfort due to bacterial activity.
There are changes in lactase activity with age (Swagerty et al., 2002). All infants, with the exception of those with a congenital defect, are born with high levels of lactase (Jarvis & Miller, 2002). Lactase activity can be detected as early as week eight of gestation and activity will continue to increase until its peak, which is around week 34 of gestation (Lomer et al., 2008). Following the first few months lactase will decrease and continue to dwindle with age in most racial and ethnic groups (Jarvis & Miller, 2002; Lomer et al., 2008). However, approximately 30% of the population will have continued lactase activity beyond weaning and into adulthood; this phenomenon is known as lactase persistence. Lactase persistence occurs mostly in people of northern European descent (Lomer et al., 2008).

There are two main types of lactase deficiency: primary and secondary. Primary lactase deficiency, also known as adult-type hypolactasia, lactase non-persistence, or hereditary lactase deficiency, is the absolute absence of lactase that develops in childhood at different ages in various ethnic groups (Heyman, 2006; Jarvis & Miller, 2002). This form of lactase deficiency is genetically determined and is an autosomal recessive trait (Jarvis & Miller, 2002). Primary lactase deficiency is the most common cause of lactose intolerance and lactose malabsorption. Whereas secondary lactase deficiency is a result from a small bowel injury such as gastroenteritis, persistent diarrhea, small bowel overgrowth, chemotherapy, or other injuries to the small intestinal mucosa (Heyman, 2006; Jarvis & Miller, 2002).
Epidemiology

An estimated 70% to 75% of the world’s adult population and 30 to 50 million of Americans suffer from lactose intolerance with varying prevalence in different ethnicities (Cleveland Clinic, 2011; Heyman, 2006; Jarvis & Miller, 2002; Nicklas, 2003; Swagerty et al., 2002; Suarez et al., 1995; Vesa et al., 2000). The lowest rates of lactose intolerance are in adult northern Europeans, North Americans, and Australasians (Heyman, 2006; Jarvis & Miller, 2002; Lomer et al., 2008). The northern European population, which has a predominance of dairy products in the diet, has a prevalence rate as little as 2% of the population (Heyman, 2006; Jarvis & Miller, 2002). In contrast, other ethnicities have a much higher rate of lactose intolerance. The prevalence ranges from 50% to 80% in Hispanics, 60% to 80% in Black and Ashkenazi Jewish populations, and nearly 100% in the Asian and American Indian people (Heyman, 2006; Jarvis & Miller, 2002; Lomer et al., 2008).

The onset is also different within the various ethnicities and populations. For example, within three to four years following weaning, the Chinese and Japanese populations lose 80% to 90% of lactase activity. The Jewish and Asian populations lose 60% to 70% of lactase activity over several years following weaning. White Northern Europeans lactase activity may not reach its lowest expression up to 18 to 20 years (Heyman, 2006; Lomer et al., 2008). There have been minimal studies on the relationship between lactose intolerance and gender. However there does not appear to be a relationship between gender the presence of lactose intolerance (Vesa et al., 2000).
Symptoms and Diagnostic Tests

The symptoms of lactose intolerance are often used in diagnosing, however, symptoms are not necessarily correlated with the degree of lactase deficiency (Heyman, 2006). Symptoms of lactose intolerance include one or more of the following: abdominal pain, diarrhea, nausea, flatulence, and bloating following the consumption of lactose or lactose-containing foods. Symptoms can vary in severity depending on the amount of lactose consumed, the degree of lactase deficiency, and the form in which the lactose is ingested (Heyman, 2006; Jarvis & Miller, 2002; Lomer et al., 2008). Fifty percent of lactase activity is required to have effective utilization of lactose without experiencing any symptoms of lactose intolerance (Lomer et al., 2008). Side effects occur when the total lactose consumed exceeds the body’s capabilities to break down to glucose and galactose (Jarvis & Miller, 2002).

The primary clinical feature of lactose intolerance is hypolactasia, which is when there is up to 75% of lactose that passes unaltered through the small intestine and is then rapidly metabolized in the colon (Swagerty et al., 2002). In lactose deficiency, there is unabsorbed lactose, which creates an osmotic load that draws both fluid and electrolytes into the lumen, which as a result creates loose stool. Additionally, unabsorbed lactose is used as a substrate for intestinal bacteria. Ultimately, the bacteria will metabolize lactose and produce volatile fatty acids such as methane, carbon dioxide, and hydrogen, which leads to flatulence. These fatty acids will thus lower the pH in the feces, which makes a fecal pH a nonspecific test for lactose malabsorption. When there is excessive gas
produced in the intestine, there is the stimulation of the intestinal nervous system leading to intestinal distention and abdominal cramping (Heyman, 2006).

There are two direct, invasive methods of assessing lactose intolerance. One is measurement of mucosal disaccharides by way of intestinal intubation and the second is the intestinal perfusion method, which is used to assess the exact amount of lactose digested (Vesa et al., 2000). Another diagnostic technique involves a hydrogen breath test, which is the least invasive and most helpful tool (Heyman, 2006). Following an overnight fast, the test involves the administration of a standardized amount of lactose, typically two grams per kilogram of weight (up to 25 grams), which is typically equivalent to the concentration of lactose in two-eight ounce glasses of milk (Eisenmann, Amann, Said, Datta, & Ledochowski, 2008; Heyman, 2006; Jarvis & Miller, 2002). The amount of hydrogen that is expired is measured over a two to three hour period. Lactose malabsorption is consistent with an increase in hydrogen expired after 60 minutes and the appearance of symptoms (Eisenmann et al., 2008; Heyman, 2006). A positive breath test, in general, is an increase in hydrogen concentration of more than 20 parts per million (ppm) above the basal value (Eisenmann et al., 2008).

Management

Milk allergies versus lactose intolerance. Common practice in lactose intolerance includes the complete aversion of milk and dairy products to avoid and improve symptoms (Heyman, 2006; Jarvis & Miller, 2002; Lomer et al., 2008; Nelms et al., 2007). Importantly, patients diagnosed with lactose intolerance are not allergic to milk, dairy products, or dairy foods and should not completely avoid these significant
calcium sources. Milk allergies involve the milk proteins and are not related to the lactose content (Dairy Council of California, 2009; Swagerty et al., 2002). A milk protein allergy involves the production of antibodies in response to one or more milk proteins that are found in milk resulting in reactions of the skin, gastrointestinal tract, and respiratory tract; a more severe consequence includes anaphylaxis which causes the swelling of airways and breathing difficulty (Dairy Council of California, 2009).

**Consequences of milk and dairy avoidance.** Individuals with lactose intolerance tend to avoid milk and dairy products to alleviate gastrointestinal symptoms (Heyman, 2006; Jarvis & Miller, 2002; Kull et al., 2009; Nicklas, 2003). Total avoidance of milk products may be problematic in calcium intake and can therefore lead to suboptimal bone mineralization increasing the risk of developing osteoporosis. Besides the numerous studies showing the role of calcium in milk and dairy products in promoting bone health, there has been recent evidence that lactose in milk and dairy products also enhances the absorption of calcium (Heyman, 2006; Nicklas, 2003). A study completed by Kull et al. (2009) on 367 men and women between 25 and 70 years old compared lactose intolerance, milk consumption, and BMD. This study found that those with self-perceived lactose intolerance had a significant self-imposed reduction in milk consumption (38% decrease), considerably lower vitamin D levels (increased PTH levels), increased bone turnover, and an increased fracture risk (Kull et al., 2009). Therefore, complete avoidance is not advised for those with lactose intolerance and dietetic consultation is warranted for those with lactose intolerance to ensure there are no
nutritional inadequacies; the monitoring of lactose intake is a better practice to determine tolerance (Heyman, 2006; Lomer et al., 2008).

Another study also found that individuals with ample lactase activity absorbed 92% of milk’s lactose and those with suboptimal levels absorbed 25% to 58% (Nicklas, 2003). These studies furthermore emphasize the importance of consumption of milk and dairy products in preventing osteoporosis. Yet another study examined the relationship between dairy intake in individuals with and without lactose in tolerance; the study included 323 male and female subjects with a wide age range. This study also found that both dietary milk and overall calcium consumption was significantly lower in those with lactose intolerance compared to those without. Also in this study, individuals with lactose intolerance generally consumed less than the recommended levels, averaging around 500 mg, and had an extreme self-limitation of food consumption rich in calcium; putting these individuals at risk for osteoporosis (Carroccio et al., 1998).

It has also been noted that children who avoid milk tend to ingest less than the recommended amounts of calcium that is required for bone calcium accretion and mineralization. Theoretically, lactose intolerance may pose a particular risk for inadequate bone mineralization during adolescence and a subsequent risk for osteoporosis later in life (Heyman, 2006). A cross-sectional study completed by Honkanen et al. (1996) examined the relationship between lactose malabsorption, calcium intake, and BMD in 2,025 perimenopausal Finnish women between the ages of 48-59. The main findings from this study were that there was a lower intake of calcium and a slightly lower BMD in women with lactose intolerance. In this study, the mean crude and
adjusted BMD among women with lactose intolerance were two- to three-percent lower than among other women (Honkanen et al., 1996). Another study that involved 246 female adolescents between the ages of 10 to 13 found that those that were either diagnosed or perceived to have lactose intolerance had a decrease in total calcium intake (approximate 212 mg reduction), reduced calcium intake exclusively from dairy foods, and reduced total dairy calcium intake compared to those without lactose intolerance. As a result, this study found a decrease in lower spinal bone mineral content values (Matlik et al., 2007).

**Lactose monitoring.** Often a good clinical history will reveal the relationship between symptoms and lactose intolerance; once suspected, a trial diagnostic lactose-free diet is tried. Typically there is a two-week trial period of a lactose-free diet; it is important that during this time, all lactose-containing foods are eliminated (Heyman, 2006). Patients are also encouraged to slowly reintroduce lactose-containing foods to insure there are no unnecessary restrictions, in that unnecessary restrictions can lead to suboptimal calcium intake. In addition, the reintroduction of lactose can reduce the symptoms of lactose intolerance (Lomer et al., 2008).

Examining the ingredient lists of foods will expose hidden sources of lactose and will aid in the monitoring of lactose intake. Key words and phrases to look for when reading an ingredient list for hidden sources of lactose include the following: condensed milk, skimmed milk powder, modified milk, evaporated milk, lactoglobulin, buttermilk, artificial cream, feta, quark, curd, ricotta, cheese, margarine, butter, cream, milk, milk
solids, or whey, or products that has a “may contain milk” statement on the package (Heyman, 2006; Jarvis & Miller, 2002; Lomer et al., 2008; Nelms et al., 2007).

Additional management options for lactose intolerance. Additional therapeutic technique involves the use of enzyme tablets or drops such as Dairy Ease, Lactaid, and so forth (Lomer et al., 2008; Nelms et al., 2007). Lactose-containing foods may also be tolerated with a commercial lactase tablet, which like the bacterial cultures in yogurt, aids in the metabolism of lactose (Onwulata, Rao, & Vankineni, 1989). These drugs are intended to help with the digestion of dairy products and are either added to food or taken prior to a meal or snack. Similarly, there are various products that have lactase added to the product to aid in tolerance. Although the goal for lactase enzyme replacement is to aid in lactose digestion, this is not always the case and are not effective in everyone (Lomer et al., 2008).

Lactose Content in Food

As stated, dairy sources are known for containing lactose. There is approximately 11 grams of lactose per one cup of milk, 9 grams per one cup of ice cream, and 1 to 2 grams per one ounce of cheese (Lomer et al., 2008; Nelms et al., 2007). Table 1 illustrates a comparison of milk and dairy products high in lactose (5-8 grams of lactose per serving) and products with a lower lactose content (0-2 grams of lactose per serving; Cleveland Clinic, 2011; National Digestive Diseases Information Clearing House, 2009). Although calcium fortified foods and supplements are often considered for this population (Heyman, 2006; Lomer et al., 2008; Nelms et al., 2007), there are dairy-products that may be suitable for consumption despite containing lactose such as
Table 1

Comparison of Milk and Dairy Products High in Lactose (5-8 Grams of Lactose Per Serving) and Products With a Lower Lactose Content (0-2 Grams of Lactose Per Serving)

<table>
<thead>
<tr>
<th>Category</th>
<th>Food item</th>
<th>Serving Size</th>
</tr>
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<tbody>
<tr>
<td>High-lactose containing milk and dairy products (5-8 grams of lactose per serving)</td>
<td>Milk, whole, reduced-fat, fat-free, buttermilk</td>
<td>½ cup</td>
</tr>
<tr>
<td></td>
<td>Evaporated milk</td>
<td>3 tablespoons</td>
</tr>
<tr>
<td></td>
<td>Condensed milk</td>
<td>¼ cup</td>
</tr>
<tr>
<td></td>
<td>Cheese spread</td>
<td>2 ounces</td>
</tr>
<tr>
<td></td>
<td>Cottage cheese</td>
<td>¼ cup</td>
</tr>
<tr>
<td></td>
<td>Ricotta cheese</td>
<td>¼ cup</td>
</tr>
<tr>
<td></td>
<td>Half-and-half</td>
<td>½ cup</td>
</tr>
<tr>
<td></td>
<td>Yogurt, plain</td>
<td>½ cup</td>
</tr>
<tr>
<td></td>
<td>Ice cream</td>
<td>¼ cup</td>
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<td></td>
<td>Ice milk</td>
<td>¼ cup</td>
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<td></td>
<td>Sour cream</td>
<td>½ cup</td>
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<td></td>
<td>Heavy cream</td>
<td>½ cup</td>
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<tr>
<td>Low-lactose containing milk and dairy products (0-2 grams of lactose per serving)</td>
<td>Milk, treated with lactase enzyme</td>
<td>½ cup</td>
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<td></td>
<td>Sherbet</td>
<td>½ cup</td>
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<tr>
<td></td>
<td>Aged cheese, such as blue, brick, cheddar, Colby, Swiss, Parmesan</td>
<td>1 ounce</td>
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<td></td>
<td>Processed cheese</td>
<td>1 ounce</td>
</tr>
<tr>
<td></td>
<td>Butter</td>
<td>1 teaspoon</td>
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</tbody>
</table>

Note. Cleveland Clinic, 2011; National Digestive Diseases Information Clearing House, 2011

yogurt, hard cheeses, and lactase containing milk (Jarvis et al., 2002; Nelms et al., 2007; Onwulata et al., 1989).

Other low lactose-containing foods that may be tolerated include yogurt. For example, yogurt with active and live bacterial cultures is a good source of calcium (415 mg/1 cup) and vitamin D for those with lactose intolerance. The bacterial cultures in the yogurt are able to convert the lactose to lactic acid; which may allow yogurt with live
active cultures to be better tolerated in lactose intolerance compared to the yogurts without (National Digestive Diseases Information Clearinghouse, 2009). Lactose-free milk and nondairy foods would be tolerated by an individual with lactose intolerance. Lactose-free milk, nondairy creamers, nondairy whipped topping, almond, rice, or soymilk, soy yogurt or soy cheese, and soy-based sour cream are all lactose-free milk and nondairy foods that are tolerated with lactose intolerance (Lomer et al., 2008; Nelms et al., 2007).

Tolerance for dairy foods appears to vary for individuals (Heyman, 2006; Nicklas, 2003). It appears that the consumption of whole milk is better tolerated compared to lower-fat milks and chocolate milk. Also, cheeses and cultured-containing dairy foods are tolerated better than milk (Nicklas, 2003). Some patients with lactose intolerance can tolerate low-lactose dairy foods that contain little lactose (one gram or less), which includes one to two ounces of aged cheeses such as Swiss, cheddar, or parmesan, two tablespoons cream cheese, one-third cup cottage cheese, or one half cup ricotta cheese (Jarvis et al., 2002; Lomer et al., 2008; Nelms et al., 2007).

**Calcium**

Calcium is the most abundant mineral in the human body and is required for numerous body processes (Bailey et al., 2010; Linus Pauling Institute, 2010; Litchford, 2011; National Institutes of Health: Office of Dietary Supplements, 2012). The two different types of calcium found in the body have very distinct roles: blood and bone calcium. Ninety-nine percent of calcium in the body is found in bones and teeth (J. Brown, 2008; Linus Pauling Institute, 2010; National Institutes of Health: Office of
Dietary Supplements, 2012). In bone, calcium provides the framework for skeletal system by providing structure and hardness (J. Brown, 2008; National Institutes of Health: Office of Dietary Supplements, 2012). Calcium is the primary constituent of bone and is important for bone remodeling. Bone acts as a storage reservoir for calcium that can be released when there is inadequate blood calcium (Nelms et al., 2007).

The other 1% of calcium in the body is located in the blood (J. Brown, 2008; National Institutes of Health: Office of Dietary Supplements, 2012). Even though there is a small concentration of calcium in the blood, the homeostasis of blood calcium is critical. Blood calcium levels need to be tightly maintained between the ranges of 8.5 to 10.2 mg/dL (Litchford, 2011). Maintaining blood calcium in this tight range is imperative for cell signaling for blood clotting, hormone secretion, and nerve and muscle contraction (Bailey et al., 2010; Linus Pauling Institute, 2010; Litchford, 2011; National Institutes of Health: Office of Dietary Supplements, 2012).

**Functions of Calcium**

**Blood calcium.** Calcium in the blood has an active role in moderating the body’s essential functions. In particular, calcium is required for cell signaling for processes such as blood clot formation and nerve and muscle contraction (Bailey et al., 2010; Linus Pauling Institute, 2010; Litchford, 2011; National Institutes of Health: Office of Dietary Supplements, 2012). In the blood, calcium can be found in two forms; bound or unbound to proteins. The predominant protein to which calcium is bound is albumin. Calcium that is bound to proteins acts as a reserve and has no direct action in the body. Unbound calcium, however, actively mediates body processes (The Merck Manual, 2008).
Excitable cells such as skeletal muscle and nerve cells are highly regulated by calcium. The regulation of calcium occurs through voltage-dependent calcium channels that are located in cell membranes. These calcium channels determine the flow and concentration of calcium ions within the cell to create an action such as a nerve impulse or a muscle contraction. In a muscle cell, for example, an action potential originating from the central nervous system activates voltage-gated sodium channels, which in return activates calcium channels that allow for calcium ions to enter into the cell. Following its entry, calcium ions will bind to activator proteins, such as the neurotransmitter acetylcholine, to allow for further release of calcium from storage vesicles located within the cell. Calcium ions can then bind to a protein called troponin-c to initiate a cascade of events leading to a muscle contraction. The energy for the muscle contraction is also depended on calcium and is derived from the breakdown of muscle glycogen when calcium ions bind to a protein called calmodulin (Linus Pauling Institute, 2010).

Along with contributing to muscle and nerve contraction, calcium is also required for blood clot formation. Calcium works along with vitamin K to activate clotting factors, or proteins, that are dependent on one another (The Franklin Institute, 2013; Linus Pauling Institute, 2010). Following the binding of calcium ions, a coagulation cascade involving seven vitamin K-dependent clotting factors occurs (Linus Pauling Institute 2010, Nelms et al., 2007). The seven clotting factors then work to form blood clots to stop bleeding and form a scab (The Franklin Institute, 2013; Linus Pauling Institute, 2010). The primary factors that make up core of the coagulation cascade
include factors II (prothrombin), VII, IX, and X (Linus Pauling Institute, 2010). Prothrombin and thrombin are particularly important in blood clot formation.

In order to bind calcium, vitamin K-dependent gamma-carboxylation of glutamic acid residues must occur. Following the vitamin K-dependent gamma-carboxylation of glutamic acids, prothrombin is synthesized in the liver. Thrombin, which is a serine protease protein, is activated through prothrombin and it converts fibrinogen to insoluble strands of fibrin to then catalyze additional coagulation reactions (Linus Pauling Institute, 2010). Thrombin enhances platelet aggregation through the activation of protease-activated receptors (The Franklin Institute, 2013). To enhance the action of thrombin, which is also the activated form of prothrombin, protein Z promotes the association of phospholipids within the cell membranes. Proteins C, S, and Z all have an anticoagulatory function that controls and balances the coagulation cascade (Linus Pauling Institute, 2010). Without adequate calcium and vitamin K, it takes the body longer to form a clot resulting in an increased the risk of bleeding to death (The Franklin Institute, 2013).

**Physiology of Calcium and Bone**

**Types of bone.** The major component of bones is called “osseous tissue” and makes up the majority of bone mass (Nelms et al., 2007). Within the osseous tissue, there are two major constituents: an organic component that is permeated by an inorganic component (Heaney, 2000; Nelms et al., 2007). The adult skeleton is composed of two main types of bone: cortical bone and trabecular bone. Approximately 80% of the skeleton is of cortical bone and 20% is made of trabecular bone (Clark, 2008).
Cortical bone is the dense and compact portion of the bone that envelops the bone marrow (Nelms et al., 2007). Cortical bone is found in the exterior of bone such as the shaft of the femur. The major action of cortical bone is to provide both structure and protection and is therefore metabolically inactive, whereas trabecular bone is interspersed within the bone marrow to create a honeycomb-like network (Clark, 2008; Nelms et al., 2007). Trabecular bone can be found in the head of long bones and the bones of the vertebrae. Unlike cortical bone, trabecular bone is metabolically active and is influenced by hormones and maintaining calcium homeostasis. Both cortical bone and trabecular bone contain osteon units, which are the fundamental functional unit of bone. Osteons are located throughout bone and consist of lamellae, concentric circles that surround the Haversian canal. The Haversian canal is the central canal that contains nerves and the bone’s blood supply. Depending on the location, bones have varying ratios of cortical to trabecular bone (Clark, 2008).

Cortical bone is the major component of bone and is also referred to as “compact bone” and is the inorganic component of osseous tissue (Clark, 2008; Nelms et al., 2007). The bulk material in bone that is responsible for structural and mechanical is made of up inorganic properties that consist mainly of hydroxyapatite [Ca10(PO4)6(OH)2], which contains large amounts of crystallized calcium, phosphorus, and protein (Heaney, 2000; Linus Pauling Institute, 2010). The inorganic element provides stiffness to support an individual’s body weight without bending (Clark, 2008; Nelms et al., 2007). Typically, cortical bone is less metabolically active compared to trabecular bone, but it provides the
major function of the skeletal system, which is to support the body, protect organs, and store and release calcium (Clark, 2008; Nelms et al., 2007).

Trabecular bone, which is synonymous with “cancellous bone” or “spongy bone,” is less dense, softer, weaker, and not as stiff compared to cortical bone (Clark, 2008). Ninety percent of the organic element consists of protein collagen, which allows flexibility in the bones; without this organic component, bones would easily shatter under stress (Heaney, 2000; Nelms et al., 2007). Trabecular bone is typically located at the ends of long bones and within the interior of vertebrae. This portion of bone is where red bone marrow lies and is also where hematopoiesis, or the production of blood cells, occurs. Compared to cortical bone, trabecular bone has a greater surface area making it an ideal location for metabolic activity such as the exchange of calcium ions. The trabecular bone is severely affected by osteoporosis compared to cortical bone (Clark, 2008). Without calcium, the inorganic and organic component would be lacking and without these two components working in unison, the bones would be at risk for breakage.

**Calcium homeostasis.** Even though calcium in blood and bone has separate roles in their action in the body, the two forms are intimately related through hormone secretion. Maintaining blood calcium homeostasis in a tight range is critical to perform essential biological reactions. If calcium ingestion does not match calcium excretion, a cascade of events orchestrated by calcitriol from the thyroid gland and parathyroid hormone (PTH) from the parathyroid gland occurs to maintain blood calcium levels in the normal range (Heaney, 2000; The Merck Manual, 2008). To maintain a steady level
of calcium in the cells and blood, the body precisely controls the mobilization of calcium from bones through a complex mechanism involving the parathyroid glands (Linus Pauling Institute; The Merck Manual, 2008; Nelms et al., 2007). Three mechanisms are involved in normalizing serum calcium concentration. The first mechanism is through modulation of intestinal absorption of dietary calcium, the second is by acting on the kidneys to either decrease or increase calcium reabsorption, and the third mechanism is through bone formation or resorption (R. Brown, 2003; Heaney, 2000; Linus Pauling Institute, 2010; The Merck Manual 2008; Nelms et al., 2007). The primary bone metabolism regulators, however, are vitamin D, calcitonin, and parathyroid hormone, or PTH (Nelms et al., 2007).

The most important endocrine regulator of calcium is PTH. The four parathyroid glands surround the thyroid gland around the neck and releases PTH, which is intimately associated with both calcium and vitamin D (Linus Pauling Institute, 2010; The Merck Manual, 2008). Parathyroid hormone is synthesized as a preprohormone and is packaged within the Golgi apparatus into secretory vesicles to be secreted through exocytosis into the blood. Parathyroid hormone targets cells both in bone and the kidneys (R. Brown, 2003). When blood calcium decreases, the parathyroid glands sense the decline and secrete PTH into the circulation. The main physiological effects of PTH include decreasing calcium excretion from the kidneys, promoting the utilization of calcium stored in bone, and activating circulating vitamin D3 to its active form 1,25 dihydroxycholecalciferol in the kidney resulting in increased calcium absorption (R.
Circulating levels of PTH regulates the amount of skeletal remodeling (Heaney, 2000; The Merck Manual, 2008). The exact mechanism of how PTH mobilizes calcium from bone is obscure, but it is hypothesized that PTH triggers osteoclast activity. The stimulation of osteoclasts can then reabsorb bone minerals, which results in the liberation of calcium to then go into the blood circulation (R. Brown, 2003). However, PTH levels or blood calcium lab values alone are not indicative of bone mass status; scans such as the duel-energy x-ray absorptiometry are better indicators for bone mineral status. Another action of PTH is the suppression of calcium loss in the urine (R. Brown, 2003; Heaney, 2000; Linus Pauling Institute, 2010; The Merck Manual 2008). Parathyroid hormones inhibit the loss of calcium in the urine through stimulation of tubular reabsorption of calcium (R. Brown, 2003).

Parathyroid hormone also enhances the absorption of calcium from the small intestine in order to elevate blood levels (R. Brown, 2003; Heaney, 2000; Linus Pauling Institute, 2010; The Merck Manual, 2008). This process is stimulated by PTH but does so indirectly through the activation of vitamin D in the kidney (R. Brown, 2003). Vitamin D is considered to be both a fat-soluble vitamin and a steroid hormone because it can be synthesized in the body. Vitamin D is most notably known for its role in bone formation and is required for the metabolism for calcium and phosphorus in the intestines and bones (R. Brown, 2003; Linus Pauling Institute, 2010; Nelms et al., 2007; National Institutes of Health: Office of Dietary Supplements, 2012).
The two major forms of vitamin D in the body include ergocalciferol (vitamin D2) and cholecalciferol (vitamin D3). Ergocalciferol and cholecalciferol have the same biological activity and are only slightly different in their molecular structure (Nelms et al., 2007). Vitamin D can be obtained in the diet or through the epidermis of the skin. However, both ergocalciferol and cholecalciferol are inactive forms of vitamin D and must travel to both the liver and kidneys to form 1,25-dihydroxycholecalciferol, which is also referred to as 1,25-dihydroxyvitamin D (Linus Pauling Institute, 2010; Nelms et al., 2007).

Ergocalciferol is produced through the plant steroid ergosterol following ultraviolet irradiation. Once consumed in the diet and absorbed in the intestines, ergocalciferol is converted to cholecalciferol (Nelms et al., 2007). Following this conversion, cholecalciferol can continue to the liver where the first hydroxyl-group is added forming 25-hydroxycholecalciferol or also known as 25-hydroxyvitamin D, a major circulating form of vitamin D (Linus Pauling Institute, 2010; Nelms et al., 2007). Elevations in PTH responding to decreased blood calcium level will increase the activity of 25-hydroxyvitamin D3-1-hydroxylase in the kidney to convert 25-hydroxyvitamin D3 to its activated form: 1,25 dihydroxyvitamin D3, which is also known as calcitriol (R. Brown, 2003; Linus Pauling Institute, 2010).

Cholecalciferol has a similar path as ergocalciferol. Cholecalciferol is naturally occurring and is produced photochemically. When 7-dehydrocholesterol, a precursor molecule located in the epidermis of the skin, is exposed to ultraviolet light, cholecalciferol is produced. Once cholecalciferol is produced, it can then follow the
same path to the liver and kidneys eventually forming 1,25-dihydroxyvitamin D, or calcitriol (Nelms et al., 2007). Calcitriol is primarily responsible for signaling for increased calcium absorption in the small intestine (R. Brown, 2003; Linus Pauling Institute, 2010). This phenomenon occurs by vitamin D inducing the synthesis of calcium-binding proteins, calbindin, that are located within the intestinal epithelial cells which then allows for the absorption of calcium into the blood (R. Brown, 2003). Calcitriol also work with PTH to stimulate the release of calcium through the activation of osteoclasts, which are bone-resorbing cells, and decreasing urinary excretion of calcium and increasing reabsorption in the kidneys (Linus Pauling Institute, 2010; Nelms et al., 2007).

Once blood calcium returns to normal range, PTH released from the parathyroid glands cease and the kidneys will then excrete any excess calcium in the urine (Linus Pauling Institute, 2010; The Merck Manual, 2008). The hormone calcitonin from thyroid glands works opposite of PTH and acts to reduce blood calcium. The parafollicular, or “C” cells, on the thyroid gland secretes calcitonin when there is an elevated blood calcium. Calcitonin lowers calcium through three different mechanisms; the first through the inhibition of absorption in intestines, the second through the inhibition of osteoclast activity and the promotion of osteoblasts in bones, and the third through the promotion of calcium excretion through the inhibition of resorption in the kidneys (Nelms et al., 2007).

**Bone modeling.** Bones are constantly rebuilding to adapt for new loads, repair damage, and to regulate extracellular blood calcium (Heaney, 2000; Linus Pauling Institute; Nelms et al., 2007). Throughout life, bone grows both longitudinally and
radially by modeling and remodeling. During childhood and adolescence, longitudinal and radial growth and development rapidly occur. Throughout this time, bones grow at the “growth plates” in long bones and proliferates the epiphyseal and metaphyseal. Following this proliferation, mineralization will occur and form new bone (Clark, 2008). The typical sequence of bone remodeling involves first osteoclastic resorption followed by osteoblastic formation to fill the cavity (Clark, 2008; Heaney, 2000; Linus Pauling Institute, 2010; Nelms et al., 2007). Osteoclasts are cells that break down bone my removing its mineralized matrix whereas osteoblasts are cells that aid in the creation of new bone (Clark, 2008; Heaney, 2000; Linus Pauling Institute, 2010; Nelms et al., 2007). Bone tissue is dynamic and is constantly modeling and remodeling itself (Clark, 2008; Heaney, 2000; Linus Pauling Institute, 2010).

Bone modeling involves changing shape and structure to adapt for physiological needs or mechanical forces that the skeletal system encounters. Bone modeling includes widening or changing of axis through either removal or addition of bone from the response of biochemical forces and the actions of osteoblasts and osteoclasts. Circumstances such as hypoparathyroidism (low PTH), renal osteodystrophy (bone mineralization deficiency), or through the treatment with anabolic agents can cause increased bone modeling. In adults, bone remodeling occurs more frequently compared to bone modeling (Clark, 2008).

**Bone remodeling.** Bone remodeling prevents the accumulation of bone microdamage. Bone remodeling focuses on renewing bone to maintain strength and mineral homeostasis through the removal of old bone and mineralization of new bone.
Remodeling is also tightly coupled with osteoclasts and osteoblasts that sequentially create the newly synthesized bone. This process involves the discrete removal of old bone and then replacing it with proteinaceous bone to be mineralized into new bone through four sequential phases; activation, resorption, reversal, and formation (Clark, 2008).

The activation process involves the recruitment and activation of mononuclear monocyte osteoclast precursors, which removes the endosteum, which is the membrane lining of the medullary cavity. Following the removal of the bone endosteum, the formation of multinucleated preosteoclasts occurs and they can then bind to the bone matrix from interactions with integrin receptors to form a seal around the bone-resorbing compartments. To help mobilize bone mineral, osteoclasts lower the pH of the bone-resorbing compartment to as low as 4.5. Osteoclasts release tartrate-resistant acid phosphatase, cathepsin K, matrix metalloproteinase 9, and gelatinase to consume the organic matrix. The digestion of the organic matrix forms the Howship’s lacunae in trabecular bone and the Haversian canals in cortical bone. The osteoclast process of bone resorption takes approximately two to four weeks of the remodeling cycle. The process ceases following apoptosis of multinucleated osteoclasts (Clark, 2008).

Following bone resorption, the reversal phase of bone formation occurs. During this phase, the cavities that were created during resorption contain cells such as monocytes, osteocytes, and preosteoblasts. These mononuclear cells are recruited to begin the process of new bone formation (Clark, 2008). The primary bone cell in new bone formation involves osteoblasts. Osteoblasts produce an osteoid matrix, which
consists of collagen (Clark, 2008; Heaney, 2000; Linus Pauling Institute, 2010; Nelms et al., 2007). Osteoblasts also release small, membrane-bound vesicles that contain calcium and phosphate to destroy mineralization inhibitors including pyrophosphate and proteoglycans (Clark, 2008). Once osteoblasts are surrounded within the matrix of the bone, they become osteocytes and create an osteocyte network within bone (Clark, 2008; Linus Pauling Institute, 2010; Nelms et al., 2007). An estimated 50 to 70% of osteoblasts undergo apoptosis following the completion of new bone formation while the other 30 to 50% becoming bone-lining cells. The bone-lining cells serve as blood-bone barrier but can also dedifferentiate itself back to osteoblasts when necessary. The process of bone formation takes approximately four to six months (Clark, 2008).

The completion of each bone remodeling cycle results in the production of a new osteon and is essentially the same in both cortical and trabecular bone. However, a low cortical bone turnover rate is about two to three percent per year, whereas trabecular bone is higher because it requires more maintenance to maintain mechanical strength. When there are low levels of calcium or phosphorus in the body, there is an increase in bone remodeling. The demand for calcium or phosphorus is often met through osteoclastic resorption. It is critical to have ongoing bone remodeling because it ensures a continuous supply of new bone which is better capable of exchanging ions with the extracellular fluid to maintain calcium homeostasis (Clark, 2008).
Peak Bone Mass

Importance of Reaching Peak Bone Mass

Peak bone mass (PBM) can be defined as the total amount of body tissue present following the conclusion of skeletal maturation. Peak bone mass serves as a particularly important predictor of osteoporosis and fracture risk (Bonjour, Theintz, Law, Slosman, & Rizzoli, 1994; Clark, 2008). There are several determinants of PBM; including genetics, gender, nutrition (calcium intake), and physical activity (Rizzoli, Bianchi, Garabedian, & Moreno, 2009). The skeletal system is in a continual state of change throughout life. However adolescence is the period of greatest skeletal development. Greater than 90% of bone mass formation occurs before the age of 20 (Nicklas, O’Neil, & Fulgoni, 2009). It is estimated that the average age of peak BMD attainment in healthy individuals is between 18 to 20 years in females and 20 to 23 in males (Boot et al., 2010). Mature height is typically reached between the ages of 16 to 18 in females and 18 to 20 in males (Nelms et al., 2007; Nicklas et al., 2009).

Fracture and osteoporosis risk is dependent on the PBM obtained and the rate of bone loss in the later years. The consequences of not attaining PBM include an increased risk for the development of osteoporosis and fractures (Bonjour et al., 1994; Boot et al., 2010; Clark, 2008; Rizzoli et al., 2009). A study completed on 501 people, 141 males and 360 females, between the ages of 13 and 29 years old examined the relationship between PBM and fracture risk. This study found that subjects of both sexes who had a fracture had a significant lower total body BMD. In addition, participants who
experienced a fracture and had a lower lumbar spine BMD had a significantly decreased total body BMD (Boot et al., 2010).

**Puberty and Peak Bone Mass**

Puberty is particularly important for developing bone mass and strength. Fifty to 70% of bone mass is accountable for bone strength (Bonjour et al., 1994; Clark, 2008). Puberty primarily affects bone size rather than the volumetric mineral density (Bonjour et al., 1994). Puberty is a critical time for skeletal formation and therefore adequate calcium and vitamin D intake are essential. A study done by Kalkwarf, Khoury, and Lanphear (2003) examined the data from the third National Health Examination Survey which looked at 3,251 non-Hispanic, White women who were 20 years or older. The authors inquired the frequency in which the subjects consumed milk during childhood (ages 5-12) and during adolescence (ages 13-17). The study found that low milk intake during adolescence was associated with a 3% decrease in hipbone mineral and density content and that low milk intake during childhood were at a two-fold greater risk of experiencing a fracture (Kalkwarf et al., 2003). A two-year intervention study completed by Matkovic, Fontana, Tominac, Goel, and Chesnut (1990) examined the use of calcium supplementation on bone mass in adolescent females. Overall, the study suggested that inadequate intake of calcium (200-500 mg/day) translates to inadequate calcium retention, despite being a time-period of increased absorption. Other studies also found that elevating calcium intake during adolescence and young adulthood will reduce or halt bone loss and reduce osteoporotic fractures as adults showing the importance of calcium intake in preventing bone health (Heaney, 2000).
Puberty is also a time of increased fracture incidence in adolescence due to asynchrony of length gain compared to bone mass growth. Around the beginning of the third decade of life, there is variability in BMD in the axial and appendicular skeleton, which poses a risk for osteoporotic fractures. Sites that experience the greatest variance, thus being susceptible to osteoporotic fractures, include areas such as the lumbar spine and the femoral neck (Bonjour et al., 1994). In order to delay or prevent the development of osteoporosis, it is essential the PBM is obtained during adolescence.

Factors Affecting Peak Bone Mass

**Non-modifiable risk factors for low bone mass.** There are numerous non-modifiable risk factors that contribute to low bone mass. Genetics, gender, and ethnicity are all non-modifiable factors that contribute to bone density.

*Hereditary studies on bone mass.* It is estimated that 50% to 85% of BMD is genetically predetermined (Krall & Dawson-Hughes, 1993; Ralston & Uitterlinden, 2010; Sigurdsson, Hallforsson, Styrkarsdottir, Kristjansson, & Stefansson, 2008). Most hereditary research has been done through twin or familial studies due to familial resemblances and a common environment and lifestyle habits. One study examined 58 female and 7 male twin pairs to determine the importance of genetic factors of determining bone mass (Pocock et al., 1987). This study found a strong genetic component in bone mass of the spine and proximal femur (Pocock et al., 1987). Another study, completed by Krall and Dawson-Hughes (1993), looked at genetic resemblance in BMD among 160 adult members of 40 families in five skeletal sites. In this study, each family had a postmenopausal mother, a premenopausal daughter, a son, and the
children’s father. The results of this study observed associations in BMD between parents and children in most skeletal sites measured (Krall & Dawson-Hughes, 1993).

A two-year intervention study by Matkovic et al. (1990) examined hereditary influences of bone mass by comparing the subjects to their parents’ bone mass. The study found that by the age of 16, the daughters will accumulate 90-97% of the bone mass of their mothers (Matkovic et al., 1990). Yet another familial study completed by Sigurdsson et al. (2008) looked at 440 nuclear families with a total of 869 first-degree relatives with the aim to assess the impact of genetics and the environment on low bone mass. The study found that lumbar and hip BMD were due to a genetic predisposition, accounting for more than 60% of the variation in BMD. More specifically, the researchers observed that if a BMD fell below one to two standard deviations below the age-matched BMD mean, the chances of finding the same inadequate bone mass in that skeletal sight in a first-degree relative was 28-36%. Also, there was a significant correlation between any first-degree relative pairs (Sigurdsson et al., 2008).

**Gender and bone mass.** Although puberty is a critical time-period for both males and females, there are some important gender differences to note. Males have a more prolonged period of bone maturation compared to females; making puberty an especially crucial period of adolescent females (Bonjour et al., 1994; Kalkwarf et al., 2003; Matvkovic et al., 1990). Another difference related to gender is that males have a larger increase in bone size and thickness compared to females (Bonjour et al., 1994). In addition, a study completed by Taaffe et al. (2003) looked at 812 males and females and compared their bone mass. The study found that men had a greater bone density
compared to their female counterparts. In addition, men also had a 4.3% greater volumetric bone density of the mid-femur in men compared to women (Taaffe et al., 2003).

**Ethnicity and bone mass.** The association between ethnicity differences and BMD, fracture risk and osteoporosis risk has been well documented (Megyesi, Hunt, & Brody, 2011). For example, a study conducted by Taaffe et al. (2003) that involved 812 Black and Caucasian male and females (197 Caucasian women, 225 Black women, 242 Caucasian men, and 148 Black men) examined the racial and skeletal differences between the different populations. This study found that Black women had a greater total (4.3%) and cortical (5.7%) area compared to Caucasian women (Taaffe et al., 2003).

Another study on 75 Black and 75 White females between the ages of two to 20 years old found significant differences between the two populations (Gilsanz, Roe, Mora, Costin, & Goodman, 1991). In particular, vertebral bone density was significantly greater in the Black subjects compare to the White participants in adolescence when the subjects were approaching skeletal maturity (Gilsanz et al., 1991).

**Modifiable risk factors for low bone mass.** There are modifiable risk factors that contribute to low bone mass. Physical activity, calcium, and vitamin D intake, and dairy intake are all factors within an individual’s control for developing bone mass.

**Physical activity and bone mass.** The Centers for Disease Control and Prevention (Centers for Disease Control and Prevention) and the American College of Sports Medicine (ACSM) made the recommendation that American adults should participate in 30 minutes or more of moderate-intensity physical activity on preferably all
days of the week (Centers for Disease Control and Prevention, 2010; Haskell et al., 2007). High impact activities such as jumping, weight lifting, gymnastics, and many more all improve BMD and PBM. The accrual of BMD occurs by exceeding the strain threshold, adding stress, which in turn increases the production of collagen, the beginning of bone formation (Guadalupe-Grau, Fuentes, Guerra, & Calbet, 2009; Haskell et al., 2007; Vicente-Rodriguez, Jimenez-Ramirez, Serrano-Sanchez, Dorado, & Calbet, 2003).

A study completed by Kanders, Dempster, and Lindsay (1988) examined the relationship of mechanical stress (physical activity) and lumbar and mid-radius bone mass in 60 women between the ages of 25 and 34 years. This study found an obvious relationship between physical activities and BMD and lumbar spine (Kanders et al., 1988). Similarly, a study completed by Vicente-Rodriguez et al. (2003) examined bone mineral content (BMC) and BMD on 104 nine-year-old boys that participated in soccer compared to sedentary children. The primary findings of this study was that there was a higher BMD in the lower limbs, lumbar spine, and femoral neck in the children who participated in soccer compared to their sedentary counterparts; there was a 4% increase lower limbs, a 2% in the lumber spine, and a 5% in the femoral neck BMD (Vicente-Rodriguez et al. al, 2003). These studies demonstrate the importance of physical activity on peak bone mass.

**Calcium and vitamin D intake and bone mass.** The relationship between calcium deficiency and osteoporosis is well established. Despite osteoporosis commonly being a condition among the elderly, the development and risk of osteoporosis begins in childhood and adolescence. Inadequate calcium intake is detrimental to bone health and
can lead to reduced bone mass and unfortunately many Americans are not consuming adequate calcium intake neither through diet alone nor with supplements (Ma, Johns, & Stafford, 2007). Between 1999 and 2004, roughly 32% of United States adults met the recommendations for calcium (Bailey et al., 2010). Kalkwarf et al. (2003) discovered that among 20 to 49 year old women who consumed less than one serving of milk per week had a bone mineral content 5.6% less than those that consume more than one milk serving per day.

Meeting the daily recommendations for calcium and vitamin D are critical for achieving optimal bone mass. Without adequate calcium and vitamin D, there is a reduction in calcium absorption, an increase in PTH concentrations, and subsequent bone loss. It has been well established in research literature the positive association to meeting both the daily calcium and vitamin D recommendations and achieving optimal BMD (Dawson-Hughes, Harris, Krall, & Dallal, 1997; Dawson-Hughes, Jacques, & Shipp, 1987; Gennari, 2001). Conversely, research has proven that inadequate calcium and vitamin D can lead to decreased bone mass, an increased fracture risk, and osteoporosis. Furthermore, calcium intakes less than 400 mg per day has an adverse impact on bone mineral status thus an increased risk of osteoporosis (Nelms et al., 2007). A study completed on 76 healthy postmenopausal women between the ages of 40 and 70 found that women with a calcium intake below 405 mg per day had a significant rate of spinal bone density loss compared to women that consumed greater than 777 mg per day (Dawson-Hughes et al., 1987).
Another study completed by Dawson-Hughes et al. (1997) on 858 healthy male and female subjects over the age of 65, found that supplementation of both calcium (500 mg elemental calcium in the form of calcium citrate) and vitamin D (700 IU of cholecalciferol) had a significant positive effect on change over three years in BMD, specifically in the femoral neck, spine, and total body. Similarly, a study on 36,282 postmenopausal women between 50 and 79 years old who were enrolled in the Women’s Health Initiative also found that supplementation of both calcium and vitamin D have beneficial effects on hip BMD. In this study, the participants received 1000 mg of elemental calcium in the form of calcium carbonate along with 400 IU of cholecalciferol daily, or a placebo and had a seven-year follow up. The primary finding in this study was a significant increase in the BMD of the hip bone (Jackson et al., 2006).

**Dairy intake and bone mass.** In the United States, the majority of calcium is consumed from foods products (Levenson & Bockman, 1994). It is estimated that around 70% of dietary calcium is derived from milk and dairy consumption and the other 30% from other sources including green vegetables, dried fruit, and drinking water (Gueguen & Pointillart, 2000). Dairy products are notably known for their association with combating osteoporosis by increasing bone density (Devine, Prince, & Bell, 1996; Heaney, 2000; Kalkwarf et al., 2003; Nicklas et al., 2009). A study by Kalkwarf et al. (2003) discovered a 3% reduction in hipbone mineral content and bone density in adolescents that had low milk intake. A study done by Devine et al. (1996) found that milk supplementation in postmenopausal women substantially improved not only calcium levels, but also 10 other key nutrients (Devine et al., 1996; Heaney, 2000). Individuals
who consumed the dairy recommendations were also more likely to meet or exceed the AI for calcium. In a study conducted to examine the role of dairy in meeting dietary calcium recommendations, it found that adolescents who did not report any dairy intake only consumed 40% of the AI for calcium. Therefore, those individuals who do not consume dairy products, such as strict vegans or individuals with lactose intolerance, must make dietary changes such as consuming fortified products to meet their calcium and other nutrient needs (Nicklas et al., 2009).

**Dietary Calcium Recommendations**

Calcium was among the nutrients that were emphasized in the 2005 Dietary Guidelines Advisory Committee (DGAC) and HP2010 due to the shortfalls of intake in both children and adults (Bailey et al., 2010; Centers for Disease Control and Prevention, 2010; Nicklas et al., 2009). Calcium’s association with debilitating diseases and conditions has subsequently caused dietary levels to be scrutinized and was a goal for Healthy People 2010 (HP2010; Bailey et al., 2010; Centers for Disease Control and Prevention, 2010). According to Healthy People 2010, meeting the dietary recommendations for calcium occurs when a person consumes 77-100% of the Adequate Intake (AI) for calcium (Centers for Disease Control and Prevention, 2010). The goal for calcium in HP2010 was to increase the number of people two years and older to meet the daily recommendations of dietary calcium through calcium-dense food such as dairy products (Bailey et al., 2010; Centers for Disease Control and Prevention, 2010).

Meeting dietary calcium requirements throughout a life cycle is critical for achieving peak bone mass, maintaining optimal bone mass, and minimizing mineral
losses to prevent osteoporosis (Nelms et al., 2007). The recommended requirements for calcium are based on a variety factors such as age, sex, and pregnancy. Table 2 reflects the Recommended Dietary Allowances (RDAs) for calcium throughout the lifecycle (National Institutes of Health: Office of Dietary Supplements, 2012).

Table 2

*Recommended Dietary Allowances (RDAs) for Daily Calcium Intake, in Milligrams (mg), Based on Age*

<table>
<thead>
<tr>
<th>Age</th>
<th>Calcium RDA (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth to 6 months</td>
<td>200</td>
</tr>
<tr>
<td>Infants 7-12 months</td>
<td>260</td>
</tr>
<tr>
<td>Children 1-3 years</td>
<td>700</td>
</tr>
<tr>
<td>Children 4-8 years</td>
<td>1000</td>
</tr>
<tr>
<td>Children 9-13 years</td>
<td>1300</td>
</tr>
<tr>
<td>Teens 14-18 years</td>
<td>1300</td>
</tr>
<tr>
<td>Adults 19-50 years</td>
<td>1000</td>
</tr>
<tr>
<td>Adult men 51-70 years</td>
<td>1000</td>
</tr>
<tr>
<td>Adult women 51-70 years</td>
<td>1200</td>
</tr>
<tr>
<td>Adults 71 years and older</td>
<td>1200</td>
</tr>
<tr>
<td>Pregnant and breastfeeding teens</td>
<td>1300</td>
</tr>
<tr>
<td>Pregnant and breastfeeding adults</td>
<td>1000</td>
</tr>
</tbody>
</table>

*Note.* National Institutes of Health: Office of Dietary Supplements, 2012

As noted in Table 2, there are changes in the recommendations for calcium throughout the lifecycle. The variances in the recommendations are due to the many factors that affect the absorption of calcium in the digestive tract (National Institutes of Health: Office of Dietary Supplements, 2012). As noted earlier, approximately 90% of peak bone mass is achieved during adolescence, making this time-period critical for adequate calcium consumption. Therefore, adolescence is particularly important for
females in that their greatest calcium absorption capabilities occur around menarche and then decrease from then on; whereas men also reach their peak absorption potential during adolescence but it is a few years later compared to females (J. Brown, 2008).

**Calcium Absorption**

Calcium can be absorbed in two ways; active transport or passive diffusion. Active transport occurs across cells mainly in the duodenum and the upper jejunum. The active transport system involves three stages: first is the entry across the enterocyte’s brush border, second the diffusion across the cytoplasm, and third is the movement across the basolateral membrane out into the extracellular fluid. Calcium will enter the cell through a positive electrochemical gradient via calcium channels that line the membrane attached to transport proteins (calmodulin and membrane calcium binding proteins). The transport proteins are the rate-limiting step for active transport of calcium entry because they are saturable. Calcium is then released into the extracellular space in two routes working against the electrochemical gradient. The first route is through a sodium-calcium pump where for every two calcium ions, three sodium ions are exchanged. The second route is through a calcium-ATPase, which is activated by calcium, calcium binding proteins, and calmodulin (Gueguen & Pointillart, 2000).

Passive diffusion occurs throughout the intestine but primarily occurs in the ileum. Typically passive diffusion involves the mass movement of water and solutes such as sodium and glucose. Unlike active transport, passive diffusion is not saturable and will thus increase with increased calcium consumption. Passive diffusion involves calcium bringing absorbed down and electrochemical gradient through intercellular
spaces, provided that calcium is in an absorbable form. Molecules such as milk proteins, such as phosphopeptides derived from casein, and amino acids, such as L-lysine and L-arginine, either makes calcium become absorbable or keeps calcium in a solution to stimulate passive diffusion (Gueguen & Pointillart, 2000).

**Calcium Bioavailability**

Bioavailability of nutrients is dependent of “absorbability,” or how much can be absorbed following consumption. In calcium, bioavailability depends on the absorbability and the ability of the calcium to be incorporated into the bone. Before the stomach can absorb calcium, it must be in a soluble form, typically ionized calcium (Ca++), in the stomach acid. Once in its soluble form or bound to a soluble molecule, calcium can cross the wall of the intestine.

**Factors Affecting Absorption Rate**

Calcium absorption depends on the habitual intake and composition of foods consumed. Absorption rates decrease as the amount of calcium intake increases. When calcium intake is low, there is an increase in transcellular calcium transport to increase absorption and vice versa when calcium intake is high. For example, around 30-50% of calcium is absorbed when a low calcium intake of 200 mg is consumed; whereas absorption rates decreases to around 10-15% in high-calcium consumption of 800 mg or more (Bronner & Pansu, 1999). Absorbability of calcium also depends on the type of food and absorption depends on the capabilities of the intestines. For example, calcium bioavailability of dairy products, particularly milk is much higher compared to nondairy sources (Gueguen & Pointillart, 2000).
**Dietary Calcium Sources**

Calcium can be found in numerous foods and supplements. However, as stated previously, the most notable source of dietary calcium is through the consumption of dairy products. Table 3 demonstrates the comparison of different dairy products and their correlating calcium content (National Institutes of Health: Office of Dietary Supplements, 2012).

Table 3

*Comparison of a Variety of Milk and Dairy Products and Calcium Content in Milligrams (mg)*

<table>
<thead>
<tr>
<th>Dairy Product</th>
<th>Serving Size</th>
<th>Calcium Content (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yogurt, plain low-fat</td>
<td>8 ounces</td>
<td>400</td>
</tr>
<tr>
<td>Yogurt, flavored low-fat</td>
<td>8 ounces</td>
<td>350</td>
</tr>
<tr>
<td>Ricotta, part skim</td>
<td>½ cup</td>
<td>337</td>
</tr>
<tr>
<td>Milk, skim</td>
<td>8 ounces</td>
<td>302</td>
</tr>
<tr>
<td>Milk, 1% low-fat</td>
<td>8 ounces</td>
<td>300</td>
</tr>
<tr>
<td>Milk, 2% low-fat</td>
<td>8 ounces</td>
<td>297</td>
</tr>
<tr>
<td>Milk, whole</td>
<td>8 ounces</td>
<td>291</td>
</tr>
<tr>
<td>Swiss cheese</td>
<td>1 ounce</td>
<td>272</td>
</tr>
<tr>
<td>Cheddar cheese</td>
<td>1 ounce</td>
<td>204</td>
</tr>
<tr>
<td>Gouda/Muenster/Provolone cheese</td>
<td>1 ounce</td>
<td>200</td>
</tr>
<tr>
<td>Mozzarella cheese, part skim</td>
<td>1 ounce</td>
<td>183</td>
</tr>
<tr>
<td>American cheese</td>
<td>1 ounce</td>
<td>150</td>
</tr>
<tr>
<td>String cheese</td>
<td>1 ounce stick</td>
<td>150</td>
</tr>
<tr>
<td>Feta cheese</td>
<td>1 ounce</td>
<td>140</td>
</tr>
<tr>
<td>Parmesan cheese, grated</td>
<td>2 tablespoons</td>
<td>138</td>
</tr>
<tr>
<td>Yogurt, frozen low-fat</td>
<td>4 ounces</td>
<td>105</td>
</tr>
<tr>
<td>Cottage cheese</td>
<td>½ cup</td>
<td>69</td>
</tr>
<tr>
<td>Cream cheese</td>
<td>1 ounce (2 tablespoons)</td>
<td>23</td>
</tr>
</tbody>
</table>

*Note.* National Institutes of Health: Office of Dietary Supplements, 2012  
*Varies by brand*
There are, however, sources of calcium in non-dairy products. Table 4 illustrates
the differences in calcium content in non-dairy products, whereas Table 5 illustrates
common calcium-fortified foods (National Institutes of Health: Office of Dietary
Supplements, 2012). A complete list of popular fortified cereals and cereal bars and
their calcium content can be found in Appendix C.

Table 4

*Calcium Content, in Milligrams (mg), of Non-Dairy Sources*

<table>
<thead>
<tr>
<th>Food Sources</th>
<th>Serving Size</th>
<th>Calcium Content (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sardines, with bones, canned</td>
<td>4</td>
<td>242</td>
</tr>
<tr>
<td>Rhubarb, cooked</td>
<td>½ cup</td>
<td>174</td>
</tr>
<tr>
<td>Molasses, blackstrap</td>
<td>1 tablespoon</td>
<td>172</td>
</tr>
<tr>
<td>Artichoke</td>
<td>1 medium</td>
<td>135</td>
</tr>
<tr>
<td>Spinach, cooked</td>
<td>½ cup</td>
<td>115</td>
</tr>
<tr>
<td>Collards, boiled</td>
<td>½ cup</td>
<td>110</td>
</tr>
<tr>
<td>Turnip greens, boiled</td>
<td>½ cup</td>
<td>99</td>
</tr>
<tr>
<td>Sesame seeds, whole, dried</td>
<td>1 tablespoon</td>
<td>88</td>
</tr>
<tr>
<td>Trout, rainbow</td>
<td>3 ounces</td>
<td>75</td>
</tr>
<tr>
<td>Sesame butter, roasted (tahini)</td>
<td>1 tablespoon</td>
<td>64</td>
</tr>
<tr>
<td>Hummus</td>
<td>½ cup</td>
<td>62</td>
</tr>
<tr>
<td>Navy beans, canned</td>
<td>½ cup</td>
<td>61</td>
</tr>
<tr>
<td>Orange</td>
<td>1 fresh</td>
<td>52</td>
</tr>
<tr>
<td>Pinto beans, canned</td>
<td>½ cup</td>
<td>51</td>
</tr>
<tr>
<td>Figs, fresh</td>
<td>2 medium</td>
<td>36</td>
</tr>
<tr>
<td>Almonds, dried</td>
<td>½ ounce (12 nuts)</td>
<td>37</td>
</tr>
<tr>
<td>Broccoli, cooked</td>
<td>½ cup</td>
<td>35</td>
</tr>
</tbody>
</table>

Note. National Institutes of Health: Office of Dietary Supplements, 2012
*Varies by brand
**Calcium added in processing
Table 5

Calcium Content, in Milligrams (mg), of Common Calcium Fortified Foods

<table>
<thead>
<tr>
<th>Food Sources</th>
<th>Serving Size</th>
<th>Calcium Content (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orange juice, calcium fortified</td>
<td>½ cup</td>
<td>300</td>
</tr>
<tr>
<td>Soymilk, calcium fortified</td>
<td>8 ounces</td>
<td>150-300*</td>
</tr>
<tr>
<td>Tofu, firm uncooked **</td>
<td>½ cup</td>
<td>258</td>
</tr>
<tr>
<td>Bread</td>
<td>1 slice</td>
<td>150</td>
</tr>
<tr>
<td>Cereal</td>
<td>Varies by brand</td>
<td>80-1000*</td>
</tr>
<tr>
<td>Cereal bars</td>
<td>1 bar</td>
<td>80-250*</td>
</tr>
<tr>
<td>Instant breakfast (e.g., Carnation Instant Breakfast)</td>
<td>1 packet</td>
<td>250</td>
</tr>
</tbody>
</table>

*Varies by brand
**Calcium added in processing

Note. National Institutes of Health: Office of Dietary Supplements, 2012

The amount of calcium absorbed depends on the food source and the absorbability. Table 6 demonstrates the amount of servings needed for high-calcium containing foods to reach the same calcium absorption capabilities of a glass of milk. For example, it would take 16.3 half-cup servings of spinach, which contains around 115 mg of calcium, to contain the same amount of absorbable calcium (Linus Pauling Institute, 2010).
Table 6

The Relationship Between High-Calcium Containing Foods and Calcium Absorbability Compared to 8 Ounces of Milk

<table>
<thead>
<tr>
<th>Food Source</th>
<th>Serving Size</th>
<th>Calcium (mg)</th>
<th>Servings Required to equal the absorbability of 8 ounces of milk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>8 ounces</td>
<td>300</td>
<td>1.0</td>
</tr>
<tr>
<td>Yogurt</td>
<td>8 ounces</td>
<td>300</td>
<td>1.0</td>
</tr>
<tr>
<td>Cheddar cheese</td>
<td>1.5 ounces</td>
<td>303</td>
<td>1.0</td>
</tr>
<tr>
<td>Tofu, with calcium, cooked</td>
<td>½ cup</td>
<td>258</td>
<td>1.2</td>
</tr>
<tr>
<td>Bok Choy, cooked</td>
<td>½ cup</td>
<td>79</td>
<td>2.3</td>
</tr>
<tr>
<td>Kale, cooked</td>
<td>½ cup</td>
<td>61</td>
<td>3.2</td>
</tr>
<tr>
<td>Broccoli, cooked</td>
<td>½ cup</td>
<td>35</td>
<td>4.5</td>
</tr>
<tr>
<td>Pinto beans, cooked</td>
<td>½ cup</td>
<td>45</td>
<td>8.1</td>
</tr>
<tr>
<td>Rhubarb, cooked</td>
<td>½ cup</td>
<td>174</td>
<td>9.5</td>
</tr>
<tr>
<td>Spinach, cooked</td>
<td>½ cup</td>
<td>115</td>
<td>16.3</td>
</tr>
</tbody>
</table>

Note. Linus Pauling Institute, 2010

There are certain components of food products that interfere with the absorption of calcium. Even though Figure 3.2 demonstrates that there are nondairy food products with calcium available, the bioavailability of calcium must be taken in consideration (Linus Pauling Institute, 2010). Populations that consume an excess of certain dietary components will be at risk of inadequate calcium intake (Levenson & Bockman, 1994; National Institutes of Health: Office of Dietary Supplements, 2012). The primary components that inhibit calcium absorption include oxalic acid and phytic acid. Foods that contain high levels of oxalic acid include beet greens, rhubarb, spinach, and peanuts (Gueguen & Pointillart, 2000; Levenson & Bockman, 1994; National Institutes of Health: Office of Dietary Supplements, 2012). Oxalic acid, also known as oxalate, is the most potent inhibitor or calcium absorption. Oxalic acid acts as an inhibitor by forming an
insoluble complex with calcium that cannot be absorbed in the gut. Similar to oxalic acid, phytic acid also forms insoluble complexes with calcium to remain unabsorbed in the intestine (Gueguen & Pointillart, 2000; Levenson & Bockman, 1994). Foods high in phytic acids include whole grains, specifically the outer husks of cereal grains (Gueguen & Pointillart, 2000; Levenson & Bockman, 1994; National Institutes of Health: Office of Dietary Supplements, 2012). Even though both oxalic acid and phytic acid are found in common foods, individuals who consume a variety of foods in their diet should not be at risk for developing a calcium deficiency.

**Fortified Calcium Sources**

Without the consumption of dairy products, fortified foods and the use of supplements may be warranted (Mangano, Walsh, Insogna, Kenny, & Kerstetter, 2011).

**Supplemental Calcium**

Supplements are another source of calcium for individuals struggling to reach the RDAs. There are four main calcium supplements: calcium carbonate, calcium citrate, calcium gluconate, and calcium gluibionate (Levenson & Bockman, 1994; Linus Pauling Institute, 2010; National Institutes of Health: Office of Dietary Supplements, 2012). Table 7 is a summary of the various calcium supplements and the amount of calcium per dose, and recommended daily dose per day (Levenson & Bockman, 1994; National Institutes of Health: Office of Dietary Supplements, 2012). The two most common forms of calcium supplements are calcium carbonate and calcium citrate (Levenson & Bockman, 1994; Linus Pauling Institute, 2010; National Institutes of Health: Office of Dietary Supplements, 2012).
Table 7

*Differences Between Calcium Supplements*

<table>
<thead>
<tr>
<th>Calcium Supplement Preparation</th>
<th>Amount of Elemental Calcium per Dose</th>
<th>Number of Doses Recommended per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium carbonate</td>
<td>200-600</td>
<td>2-5</td>
</tr>
<tr>
<td>Calcium citrate</td>
<td>200-500</td>
<td>2-5</td>
</tr>
<tr>
<td>Calcium gluconate</td>
<td>42-58.5</td>
<td>17-22</td>
</tr>
</tbody>
</table>

*Note.* Levenson & Bockman, 1994; National Institutes of Health: Office of Dietary Supplements, 2012

Calcium that is found in supplements is called elemental calcium, which during digestion is dissolved in order to be absorbed in the blood (Houtkooper, Farrell, & Mullins, 2004). Majority of commercial supplements contain around 30-40% of elemental calcium per weight and contains other cations such as magnesium, copper, iron, manganese, and zinc (Houtkooper et al., 2004; Levenson & Bockman, 1994).

Typically each calcium carbonate pill or chew provides approximately 200-600 mg of calcium (Levenson & Bockman, 1994; National Institutes of Health: Office of Dietary Supplements, 2012). Some examples of calcium carbonate supplements include various generic-chewable forms, Nephro-calci, Tums and Rolaids, Caltrate 600, and Os-Cal 500.

Calcium carbonate, the most common type of calcium supplement on the market, is inexpensive, and absorbed best when taken with food (Houtkooper et al., 2004; National Institutes of Health: Office of Dietary Supplements, 2012). The other primary calcium supplement is calcium citrate, which tends to be more expensive and is best absorbed on an empty stomach (National Institutes of Health: Office of Dietary Supplements, 2012).
Calcium citrate typically contains around 21% of calcium by weight (Levenson & Bockman, 1994). Even though calcium citrate has a lower amount of calcium compared to calcium carbonate, calcium citrate is considered to be more soluble especially in achlorhydric, low stomach acid, individuals. Some examples of calcium citrate supplements included Citracal-liquitab, Citracal, Solgar, and in other generic forms (Levenson & Bockman, 1994; National Institutes of Health: Office of Dietary Supplements, 2012).

Calcium gluconate is another possible supplement. Calcium gluconate is the preferred method for individuals with severe hypocalcaemia and is often given intravenously (Levenson & Bockman, 1994). Calcium gluconate supplement tablets are uncommon and have small percentages of elemental calcium, which would require large numbers of tablets to achieve daily adequate calcium (Houtkooper et al., 2004).

It is recommended that a person should only consume 500 mg at one time to maximize absorption (Levenson & Bockman, 1994; National Institutes of Health: Office of Dietary Supplements, 2012). Some side effects of calcium supplements can include constipation, intestinal bloating, and excessive gas. Hypercalciuria, which can lead to kidney stone formation, is a risk of excessive calcium supplementation. Calcium supplements can also impair the absorption of drugs such as atenolol, salicylates, bisphosphonates, fluoride, iron, and tetra cyclines. Contrarily, calcium absorption is inhibited with concurrent ingestion of aluminum-containing antacids, cholestyramine, phosphate, and sodium sulfate (Levenson & Bockman, 1994). Individuals using calcium supplements tend to consume a greater amount of calcium compared to nonusers; though
there still tends to be calcium deficiency even with supplement users (Mangano et al., 2011).

**Vitamin D Recommendations**

Few foods naturally contain vitamin D. Fish liver oils, the flesh of fatty fish, the liver and fat of aquatic animals (i.e., polar bears and seals), and the eggs of hens that are fed vitamin D are all natural, though extremely uncommon, sources of vitamin D (Nelms et al., 2007). In the U.S., vitamin D is primarily obtained through various fortified foods such as milk and milk products, margarine, juices, and breakfast cereals (Bailey et al., 2010, Nelms et al., 2007).

The current Recommended Dietary Allowances (RDAs) for vitamin D for males and females between the ages of 14-30 years us set at 15 mcg/day or 600 IU/day (Abrams, 2011; United States Department of Agriculture, 2012). Itself, vitamin D is biologically inactive and thus it must be metabolized in order to actively work with calcium (Linus Pauling Institute, 2010). The two major forms of vitamin D are ergocalciferol (vitamin D2) and cholecalciferol (vitamin D3) and can be retrieved from the diet. Both forms of vitamin D have the same biological function and only differ slightly in their molecular function (Nelms et al., 2007).

**Osteoporosis**

The result of reduced bone mass and the destruction of bone architecture leads to the chronic condition known as “osteoporosis” which means “porous bone” which results in an increased fracture risk (J. Brown, 2008; Edmonds, 2012). Osteoporosis is the most common bone disease in humans and is most prevalent among postmenopausal white
women; although the condition is increasing across all groups making it a major global public health concern (Nelms et al., 2007). It is estimated that in the United States, approximately 10 million individuals suffer from osteoporosis and of the 10 million, 8 million are women and 2 million are men (Edmonds, 2012; Ford, Bass, & Keathley, 2007; Nelms et al., 2007; Nicklas et al., 2009). In addition, an estimated 34 million suffer from low bone mass and are at risk for developing osteoporosis (Ford et al., 2007). It is also estimated that by 2020, one in two females and one in four 50 years or older will be at risk or will have osteoporosis (Ford et al., 2007; Edmonds, 2012).

There are two categories of osteoporosis; primary and secondary. There is no specific cause in primary osteoporosis where secondary osteoporosis is a result of a specific cause. Primary osteoporosis is the most common and is considered to be a disease of the elderly (J. Brown, 2008; Nelms et al., 2007). Other names of primary osteoporosis include “age-related osteoporosis” or “postmenopausal osteoporosis” (Nelms et al., 2007). Secondary osteoporosis accounts for 10% to 30% of osteoporosis cases and is seen primarily in premenopausal women compared to men. The use of drugs such as glucocorticoids, cytotoxic drugs, anticonvulsants, excessive thyroxine usage, heparin, and lithium, can all contribute to secondary osteoporosis (Nelms et al., 2007).

Depending on the homeostatic mechanism, osteoporosis can develop gradually or rapidly. The loss of estrogen or testosterone, such as during menopause, is an example of when accelerated bone loss can occur. The different bone tissues also have different rates of loss. In trabecular bone, up to 50% may be lost; compared to cortical bone where 35% of bone mass is typically lost (J. Brown, 2008). Therefore, skeletal areas with a high
proportion of trabecular bone, such as wrists, vertebrae, and the ends of long bones, tend to be a target for osteoporotic fractures (J. Brown, 2008; Christiansen, 1995).

**Consequences and Social Costs and Burden of Osteoporosis**

The consequences of osteoporosis are debilitating and are a major public health concern. Osteoporosis is strongly associated with both falls and bone fractures because the bands of bones become thin, porous, and weakened (J. Brown, 2008; Edmonds, 2012; Nelms et al., 2007; Nicklas et al., 2009). Porous bones are extremely susceptible to fractures and often shatter beyond repair; therefore avoiding falls is an important goal for older adults (J. Brown, 2008; Edmonds, 2012). The results of osteoporotic fractures include pain, height loss, inability to stand, and the inability to walk. More than half a million hospitalizations and over 800,000 emergency room visits were due to osteoporotic fractures in 1995 (Edmonds, 2012).

Fractures commonly occur in the spine, wrists, and hips with osteoporosis. The least debilitating of these fractures are of the wrist and only 20% of these require hospitalization (Ford et al., 2007; Edmonds, 2012; Nelms et al., 2007). Osteoporotic spine fractures occur two to three times more than hip fractures however they are often asymptomatic making them more difficult to diagnose (Nelms et al., 2007). The major source of chronic back pain, disfigurement, depression, and a slight increase in mortality are a result from spine fractures (Ford et al., 2007; Edmonds, 2012; Nelms et al., 2007). Kyphosis, which is the loss in stature by several inches and an abnormal spinal curvature, is due to multiple osteoporotic compression fractures. Kyphosis is debilitating in that it greatly restricts activities of daily living such as bending and reaching. Restrictive lung
disease and abdominal symptoms are associated with severe kyphosis and can produce
symptoms such as abdominal pain and distention, decreased appetite, early satiety,
gastroesophageal reflux disease, and constipation (Nelms et al., 2007).

Hip fractures are the most devastating fractures in osteoporosis in that it often
causes disablement thus indirectly causing a rapid decline in health and possibly death
(Edmonds, 2012; Nelms et al., 2007). Over 25% of individuals that experience a hip
related fracture are disabled within one year and almost one in five require admittance
into a long-term nursing care facility (Edmonds, 2012). Approximately 300,000
individuals with hip fractures are admitted into long-term care facilities yearly in the
United States (Edmonds, 2012; Nelms et al., 2007). Another major concern for hip
fractures is their association with depression due to the fear of falling and disabilities. A
study of women greater than 75 years older reported that 80% would prefer death rather
than nursing home placement due to hip fracture (Nelms et al., 2007). More seriously, an
estimated 20% of those with hip fractures died within one year often due to a deep vein
thrombosis or a pulmonary embolism (Ford et al., 2007; Edmonds, 2012; Nelms et al.,
2007).

Financially, the treatment of osteoporosis is costly both directly and indirectly. Indirect
costs are difficult to calculate but include reduced productivity from either
disability or premature death and reduced earnings from lost workdays for patients and
caregivers. Conversely, direct costs include inpatient and outpatient care, long-term care
facility care, home nursing care, medical equipment, and pharmaceuticals (Nelms et al.,
2007). In the United States, the direct treatment of osteoporosis cost an estimated $12 to
$18 billion annually and is estimated to reach $60 billion by the year 2030 (Ford et al., 2007; Nelms et al., 2007). Inpatient fracture treatment and care for diseases or illnesses as a consequence are a majority of these costs (Nelms et al., 2007).

The most expensive fracture to treat are those of the hips (Ford et al., 2007; Nelms et al., 2007). Between $30,000 to $40,000 is spent on the initial hospitalization care, then an additional $15,000 for follow-up and outpatient care within the first year with a total estimated accrual of $81,000 in healthcare costs due to osteoporosis in a person’s lifetime. By 2040, costs for osteoporosis care are estimated to triple. This is due to the increasing number of individuals likely to experience osteoporosis and osteoporotic-related fractures and the increasing costs of healthcare (Nelms et al., 2007).

**Diagnosis of Osteoporosis**

Bone material properties, which are determined by dietary intake, are equally important for bone strength. Individuals with osteoporosis, for example, have an abnormal bone matrix due to the lack of dietary calcium, commonly during adolescence (Clark, 2008). Bone mass and strength can be assessed through measuring bone mineral density, or BMD (Bonjour et al., 1994; Nelms et al., 2007). Therefore BMD is typically assessed to diagnose osteoporosis (Lane, 2006). The BMD is determined from when the soft tissue absorption is subtracted out (Bonjour et al., 1994). Measuring bone mass and strength can be used to determine adequate calcium intake and skeletal development and to predict osteoporotic fracture risk.

Bone mass measuring instruments can determine bone mass based on the total skeleton, which is ideal, or in local parts such as the forearm, hip, or spine (Christiansen,
Mineral bone density can be measured either invasively or non-invasively. Invasive procedures include using histomorphometric techniques to acquire biopsied material. Whereas non-invasive techniques involve using quantitative computed tomography of either single or dual energy photon or X-ray absorptiometry. All of these techniques scan the skeletal tissue and generates values that examine both thickness and the integrated mineral density (Bonjour et al., 1994; Christiansen, 1995). Locations of testing site differ but typically include either peripheral measurements, such as the forearm and heel, or axial measurements, such as the spine and hip (Christiansen, 1995).

In postmenopausal women, trabecular bone in the spine appears to disintegrate faster compared to peripheral bone (J. Brown, 2008; Christiansen, 1995). Fractures of the axial skeleton are common in osteoporotic women and are clinically important for assessment. However, it is complicated to determine bone mass in the spine due to the ratio of bone to soft tissue, the varying composition of the soft tissue, and the irregular configuration of the vertebrae, which can increase error. Therefore repeated measurements would be a better method for monitoring bone mass of this area or in combination of other BMD measurement techniques (Christiansen, 1995).

**Candidates for assessment of osteoporosis.** Measurements of BMD is indicated for all postmenopausal women over the age of 65, for younger postmenopausal women with one or more risk factors, and for younger postmenopausal women who have experienced fractures (Lane, 2006). Below is a list of indicators for candidates for BMD assessment:

- All women 65 years or older
- Postmenopausal women under the age of 65 years old:
  - If results might influence the decisions of intervention
  - One or more risk factors are present
  - History of fractures

**Duel-energy X-ray absorptiometry.** Dual-energy X-ray absorptiometry, also known as DXA or DEX, involves the use of two X-ray beams with different energy levels which examines bone composition and is the most commonly used technique for measuring bone density (Bonjour et al., 1994; Lane, 2006; Nelms et al., 2007). This form of measurement is both precise and accurate, has minimal radiation exposure, and requires minimal time makes it the preferred method of measuring BMD (Lane, 2006). Peripheral measurements (forearm and heel), axial measurements (spine and hip), and full body scans can be completed with DEXA (Bonjour et al., 1994; Christiansen, 1995). The results of DEXA scans are expressed and interpreted in the form of z- and t-scores.

**z/t scores-table.** Results of BMD tests are the best way to determine bone health. Following a DXA scan, an individual’s results are compared to the bone mass of others the same age and gender (z-score) and to a young adult at PBM. T-scores are used in diagnosis and are measured in standard deviations (National Institutes of Health: Osteoporosis and related bone diseases, 2012; see Table 8). A score of zero means that the individuals have the BMD of a normal health adult; whereas, osteoporosis is defined as a bone mineral density value that is more than 2.5 standard deviations (t-score of -2.5) below the mean for normal young White women (Edmonds, 2012; National Institutes of Health: Osteoporosis and Related Bone Diseases, 2012).
Table 8

*Interpretation of Bone Density Levels Based on t-Scores*

<table>
<thead>
<tr>
<th>Bone Density Level</th>
<th>t-Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>0 to -0.99</td>
</tr>
<tr>
<td>Low bone mass</td>
<td>-1 to -2.49</td>
</tr>
<tr>
<td>Osteoporosis</td>
<td>-2.5 or more</td>
</tr>
<tr>
<td>Severe (established) osteoporosis</td>
<td>-2.5 plus on or more osteoporotic fractures</td>
</tr>
</tbody>
</table>

*Note.* National Institutes of Health: Osteoporosis and Related Bone Diseases, 2012

**Quantitative computed tomography.** Quantitative computed tomography (QCT) scan is another method that is used to measure BMD, specifically in the lumbar spine or peripheral sites (Christiansen, 1995; Lane, 2006). This method has the advantage of measuring true volumetric (3-dimensional) BMD by using a calibrated tomographic system that contains the elements with standardized densities of calcium hydroxyapatite. Another advantage of QCT is that it is more sensitive to changes in BMD because it can distinguish between cortical and trabecular bone. Therefore, these scans are useful in following the progression of osteoporosis or monitor osteoporosis therapy (Lane, 2006).

**Ultrasound.** Ultrasound techniques utilize sound waves that are beyond the audible threshold and are affected by the physical and mechanical properties of bone (Krieg et al., 2008). Ultrasound-based techniques are used for measuring bone mass and typically examines the patella and heel (Christiansen, 1995; Krieg et al., 2008; Sharma et al., 2010). This method examines bone tissue elasticity and trabecular connectivity and
has a good precision (Sharma et al., 2010). This method has its advantages in that it is more portable, less expensive, and does not use ionizing radiation compared to DEXA. However, ultrasound devices are technologically diverse; therefore there are differing levels of validity (Krieg et al., 2008).

**Osteoporosis Risk Factors**

Many elements determine the risk of developing osteoporosis; including gender, age, ethnicity, and other lifestyle factors such as calcium intake, physical activity, and diet. Between the ages 11 to 14 for females and 13 to 17 in males, BMD rapidly increases. Following this growth spurt, BMD continues to increase at a slower rate until maximum BMD is obtained around the late 20s or 30s. Adult females lose BMD earlier and at a much quicker rate compared to men. Approximately 30% to 50% of bone mass is lost for the average White woman by the age of 70 (Nelms et al., 2007). Men have a larger body mass, greater bone mass, bigger bone size, the absence of decreased estrogen during menopause, and a shorter life span; which are all factors for the lower prevalence of osteoporosis in males (J. Brown, 2008; Nelms et al., 2007; National Institutes of Health: Office of Dietary Supplements, 2012).

**Gender.** Women genetically have lower BMD and a smaller window during adolescence to reach their PBM compared to men (Bonjour et al., 1994; Taaffe et al., 2003). In addition, menopause causes a rapid loss of estrogen, which leads to accelerated bone loss (Edmonds, 2012; Nelms et al., 2007). Therefore, women are at a much greater risk of developing osteoporosis than males. It is estimated that by the year 2020, one in two Americans over 50 years old will have or be at risk of developing osteoporosis.
There were approximately 10 million Americans with osteoporosis in 2008 and of this 10 million, 8 million were women (National Osteoporosis Foundation, 2008). Women are two to three times more likely to develop osteoporosis (Edmonds, 2012; National Osteoporosis Foundation, 2008).

**Age.** Conditions where the daily recommended dietary intake of calcium is difficult to attain increases the risk of developing osteoporosis. Around the age of 30 and throughout adulthood, bones slowly begin to lose calcium (National Institutes of Health: Office of Dietary Supplements, 2012). Bone mass tends to decrease 3% to 5% annually during the first years of menopause and continues to decrease around 1% per year following the age of 65 (Barzel, 1988; J. Brown, 2008; Nelms et al., 2007; National Institutes of Health: Office of Dietary Supplements, 2012). Postmenopausal women experience a decrease in bone density and have a greater difficulty absorbing calcium, making them a population that needs to seek for additional sources of calcium to satisfy their needs and slow the rate of bone loss (National Institutes of Health: Office of Dietary Supplements, 2012).

Unfortunately, increased calcium intake alone tends not to offset bone loss. Postmenopausal women struggle to maintain adequate bone density due to the decrease in estrogen. As a result, the lack of estrogen causes an increase in bone resorption and a decrease in calcium absorption (National Institutes of Health: Office of Dietary Supplements, 2012). There are two intracellular steroid receptors for estrogen in bone cells. Upon binding to these receptors, various genes become active and bone resorption is inhibited. Estrogen inhibits interleukin 6, which is an example of a bone resorption
stimulator, by blocking the osteoblast’s synthesis of interleukin 6 and by acting as an antagonist and competing for interleukin 6 receptors. Estrogen also encourages apoptosis of osteoclasts; without adequate estrogen, osteoclasts will have a longer life thus creating an increase in bone resorption (Barzel, 1988; National Institutes of Health: Office of Dietary Supplements, 2012).

Ethnicity. An individual’s race and ethnicity appears to influence BMD and osteoporotic fracture risk. The greatest osteoporosis incidence rates are among female Caucasian and Asian patients 50 years and older. In Hispanics, men between the ages 50 and 59 years had a higher incidence rate compared to women but the gender relationship is reversed after the age of 60. Black men also had higher occurrence rates until age 70 where the women incidence rate surpasses men (Lane, 2006). Throughout life, Blacks have the highest mean BMD values compared to Caucasians and Asians (Lane, 2006; Nelms et al., 2007). Also, hip fractures are much higher in Caucasians compared to non-Caucasians. For example, White American women report three times as many hip fractures compared to African American women (Nelms et al., 2007).

Lifestyle factors affecting osteoporosis. There are some other noteworthy risk factors that can affect calcium absorption and bone mass accretion. Individuals that are immobilized, such as on bed rest, lose bone mass rapidly. Those who are inactive also have a decreased bone mass compared to those that participate in physical activity (J. Brown, 2008). Caffeine-containing beverages along with protein, sodium, potassium, and phosphorus determine calcium losses in urine, feces, and sweat (J. Brown, 2008; National Institutes of Health: Office of Dietary Supplements, 2012). However in most
people these factors have minimal effects on overall calcium status (National Institutes of Health: Office of Dietary Supplements, 2012).

**Amenorrhea.** Another at risk population includes females of childbearing age who experience amenorrhea, which is the absence of menstrual periods, due to excessive exercise and/or inadequate energy intake (National Institutes of Health: Office of Dietary Supplements, 2012). Even though exercise is known to improve BMD, very high-intense exercise can be detrimental to bone health (Nelms et al., 2007). Typically when weight loss exceeds 10 to 15% of usual body weight, there are decreases in estrogen, luteinizing hormone (LH), and follicle stimulating hormone (FSH); which consequently causes amenorrhea (J. Brown, 2008). Similar to menopause, the lack of estrogen can cause increased osteoclast activity (Nelms et al., 2007).

Intense exercise particularly in premenopausal females can be detrimental to bone health (Nelms et al., 2007). For example, intense exercise such as ballet or gymnastics, at a young age can also delay the age of puberty by two to four years. High levels of exercise can also interrupt established menstrual cycles as well (J. Brown, 2008). Females experiencing amenorrhea need additional calcium to counteract the increased calcium losses. Amenorrhea causes increased losses of calcium in the urine, impaired calcium absorption, and a decrease in estrogen resulting in bone formation difficulties (National Institutes of Health: Office of Dietary Supplements, 2012). Typically hormone levels will return to normal once 95% of the individual’s previous weight is restored (J. Brown, 2008).
**Tobacco.** The leading cause of preventable death in the United States is tobacco smoking (J. Brown, 2008; Nelms et al., 2007). Lower bone density, increased mineral loss, and increased fracture risk in both males and females have been associated with cigarette smoking (J. Brown, 2008; Nelms et al., 2007; National Institutes of Health: Office of Dietary Supplements, 2012). Several mechanisms have an adverse affect on bone health. Tobacco smoke contains nicotine and cadmium, which are toxic to osteoblasts. There is also a decrease in calcium absorption in the intestines due to tobacco smoke (Nelms et al., 2007). Additionally, cigarette-smokers tend to have a poorer lifestyle compared to nonsmokers (J. Brown, 2008; Nelms et al., 2007). Smokers reported lower intakes of vitamin D, excessive alcohol consumption, decreased physical activity and experiences higher rates of chronic diseases compared to nonsmokers (J. Brown, 2008; Nelms et al., 2007).

**Alcohol.** Research on alcohol and BMD has been conflicting. Some studies suggest that moderate alcohol consumption, defined as less than one drink for women and two drinks for men per day, may increase BMD and decrease bone mineral loss. Conversely, excessive, heavy drinking is associated with a decreased BMD, inadequate bone formation, and a greater risk of fractures; making chronic alcoholism a major concern for osteoporosis (Nelms et al., 2007). For example, one study completed by Lucas et al. (2012), examined the relationship between alcohol consumption, smoking, and lower forearm BMD in 731 adolescent girls between the ages of 13 and 17. In this study, the researchers found that those with an earlier initiation of alcohol consumption had a significantly lower BMD (Lucas et al., 2012). Conversely, a cohort study
completed by Sommer et al. (2012) on 300 elderly women with a mean age of 68, found that women that consumed three or more alcoholic beverages per week had a significant higher BMD compared to abstainers. The authors of this study concluded that moderate alcohol consumption may be beneficial and have protective effects on bone, specifically in the femoral neck and lumbar spine, in elderly women (Sommer et al., 2012).

Chronically consuming alcohol can lead to increased calcium and magnesium losses and adversely affect overall nutritional status (J. Brown, 2008; Nelms et al., 2007; National Institutes of Health: Office of Dietary Supplements, 2012)

**Caffeine and soda consumption.** Excessive caffeine consumption has been noted with adverse effects on bone mineralization because it interferes with intestinal calcium absorption. However, there has been conflicting evidence on caffeine’s affect on bone acquisition. It is unsure whether caffeine has a direct effect on bone or if the replacements of milk products by caffeinated beverages are to blame (Heaney, 2002; Seifert, Schaechter, Hershon, & Lipshults, 2011). A large study of 84,484 American women between the ages of 14 to 59 found a relationship between caffeine intake and risk of hip fracture. In particular, individuals that consumed greater than four cups of coffee per day had a threefold increased risk of a hip fracture (Hernandez-Avila et al., 1991). A cohort study completed by Lloyd, Rollings, Kieselhorst, Eggli, and Mauger (1998) on 81 female adolescents between the ages of 12 and 18 found that those that consumed less caffeine had a significantly higher milk, thus calcium intake, compared to those with a high caffeine intake. However, in this study the researchers did not find any
significant differences between caffeine and bone mineral gain between the ages of 12 to 18 (Lloyd et al., 1998).

**High protein and sodium diets.** Inadequate calcium intake in addition to a high protein diet can be detrimental to bone density (Barzel & Massey, 1998; Skov, Haulrik, Toubro, Molgaard, & Astrup, 2002). Similarly, high sodium diets also have a negative impact on bone health (Teucher et al., 2008). The adverse effects on bone health caused by high protein and sodium diets contribute to osteoporosis risk (Barzel & Massey, 1998; Skov et al., 2002; Teucher et al., 2008).

A high-protein diet generates a large amount of acid, particularly sulfates and phosphates, and the skeletal system is used as an ion exchange buffer system to counteract the changes in acidity. Bone acts as a buffer by active resorption (Barzel & Massey, 1998). A study completed by Skov et al. (2002) on 65 subjects enrolled in a six-month weight loss trial on a high-protein diet found a decrease in bone mineral content. The high protein group consumed an average of 198 grams per day and had a significant bone mineral decline (4%) compared to low protein group (Skov et al., 2002).

Similar to high-protein diets, high-sodium diets negatively impact bone because it induces calcuria, excessive calcium in the urine, from increased bone resorption (Teucher et al., 2008). A study conducted by Teucher et al. on 11 postmenopausal women through a cross-over trial of four, 5-week periods of controlled dietary interventions, examined salt intake and overall bone health. This study found that a moderately high salt intake of 11.2 g per day found both a significant increase in urinary calcium excretion and a
negative bone balance compared to low salt intake group (3.9 g per day; Teucher et al., 2008).

**Prevention and Treatment of Osteoporosis**

The primary nutritional remedy and prevention mechanism for osteoporosis is an optimal diet that includes the RDA for both calcium and vitamin D along with a fall prevention plan that is obtained through a physical activity component (J. Brown, 2008; Nelms et al., 2007). Osteoporosis is a preventable disease with appropriate education and lifestyle changes. The target populations for osteoporosis prevention are children and adolescence in that the accretion of peak bone mass throughout development is protective against osteoporosis (Nelms et al., 2007). Emerging research is also being conducted on the effectiveness of hormone replacement therapy as both a preventative mechanism and treatment option for osteoporosis.

**Exercise and osteoporosis prevention.** Exercise and muscle strength are crucial for osteoporosis prevention and treatment in that they are directly correlated with bone mineral density (J. Brown, 2008; Eisman et al., 1993; Nelms et al., 2007). Epidemiological studies suggest that physical activity can reduce hip fractures by 20% to 50% (Feskanich, Willet, & Colditz, 2002). A 15-year longitudinal study on 84 males and 98 females from the age of 13 until age 28 monitored PBM and the influences of weight-bearing activity. The study found that there was a significant increase in BMD in those that participated in regular weight-bearing exercises. The authors noted that in their study, weight-bearing activity was the best predictor of BMD in males and body weight in females, more than calcium intake (Welten et al., 1994). The Canadian practice
guidelines for osteoporosis interventions recommend physical activity for 30 minutes or more per day, three times a week (J. Brown, 2008). Weight-bearing and impact-type physical activities are related to increased bone mineral density as a response to the stress the bones receive (J. Brown, 2008; Nelms et al., 2007). Examples of impact-type activities include walking, jogging, weight and resistance training, soccer, basketball, and gymnastics.

Athletes have been found to have a higher BMD compared to the general population and significantly more than those that are immobilized (Feskanich et al., 2002; Nelms et al., 2007). The most notable improvements in BMD occur when physical activity is included in the lifestyle during childhood and adolescence. However, exercise during adulthood has also shown beneficial effects on BMD. Research has demonstrated that activities such as walking, dancing, and jumping delay and prevent bone loss and reduce the risk of hip fractures in postmenopausal females (Nelms et al., 2007). A prospective cohort study that consisted of 61,200 women between the ages 40-77 years found that individuals who walked a minimum of fours hours per week had a substantially lower risk (41%) of experiencing a hip fracture compared to those who walked for one hour or less per week (Feskanich et al., 2002).

Another contributing factor for osteoporosis prevention and treatment includes nonimpact activities. Even though nonimpact activities have inconsistent results for BMD, they do play an important role in fall prevention (Feskanich et al., 2002; Nelms et al., 2007). Nonimpact activities are known to improve flexibility, balance, agility, and muscle strength. Therefore, a combination of both impact- and nonimpact-activities is
recommended for both the prevention and the treatment of osteoporosis (J. Brown, 2008; Feskanich et al., 2002; Nelms et al., 2007).

**Hormonal replacement therapy and osteoporosis prevention.** There is a particular concern for postmenopausal women because of hormonal changes. Women at risk of developing decreased bone mass can undergo hormone replacement therapy of estrogen and progesterone. There may also be an interaction of estrogen and the mechanical forces to build bones (National Institutes of Health: Office of Dietary Supplements, 2012). Bone remodeling can be restored through estrogen therapy from the proposed mechanism of increasing calcium absorption in the gut (Barzel, 1988; National Institutes of Health: Office of Dietary Supplements, 2012). A study on 32 women with osteoporosis found that those receiving hormone replacement therapy and a selective estrogen receptor modulator (60mg/day) experienced and increased in BMD after 12 months (Hayashi, Ina, Maeda, & Nomura, 2011).

In the National Osteoporosis Society’s position statement regarding hormone replacement therapy stated that it is an effective treatment for the protection of hip and spine fractures. However, hormone replacement therapy is only suitable for those with osteoporosis below 60 years and not for over the age of 60 and this is due to the associated risks (Bowring & Francis, 2011). Some risks of hormone replacement therapy include heart disease, stroke, blood clots, and breast cancer (National Institutes of Health: Office of Dietary Supplements, 2012)
Eating Behaviors in College Students

The college years are often the first time away for many students and is a time where independence is gained. College has notably been a period where significant lifestyle changes are established for life and have a long-lasting impact on a person’s overall health (L. P. Brown, Dresen, & Eggert, 2005; Ha & Caine-Bish; 2009; Haberman & Luffey, 1998). A well-rounded diet that includes all macro- and micronutrients in addition to a physical activity routine are known to prevent chronic diseases, such as coronary heart disease, type two diabetes mellitus, some types of cancers, strokes, and osteoporosis (Haberman & Luffey, 1998). However, the major concerns for this particular population are the overall food choices and suboptimal calcium intake.

College-era trends include a large shift of the types of foods consumed both at home and away from home (McCrory et al., 1999; Nielsen, Siega-Riz, & Popkin, 2002). The college years can generally be characterized with unhealthy eating behaviors such as skipping meals, consuming calorie-dense snacks, and participating in unhealthy weight-loss habits (Ha & Caine-Bish; 2009; Nielsen et al., 2002). Diets high in fat, saturate fat, cholesterol, and sodium and low in fiber, vitamins A, C, and E, folate, iron, and calcium are all typical components of the college-years diet (L. P. Brown et al., 2005; Ha & Caine-Bish; 2009). A study completed by Nielsen et al. (2002) found that adolescents and young adults are obtaining majority of their energy intake from restaurants and fast food places and less from at home. This shift is of concern because of the positive association between restaurants, increased portion sizes, caloric intake, and body adiposity (McCrory et al., 1999; Nielsen et al., 2002). Other trends associated
with this time-period includes a shift towards increased soft drinks, high-fat grain-based dishes, and potato consumption with a large reduction in milk intake. The composition of the meal also shifts from medium- and high-fat meat items to medium- and high-fat mixed grains (Nielsen et al., 2002).

**Calcium Intake in College Students**

Calcium intake is especially of concern because traditionally college falls during the window of PBM development and calcium consumption has notably been an area of struggle for students. Even though calcium intakes have increased from 1988-94 to 2003-04, majority of individuals are still not consuming the recommended daily values (Centers for Disease Control and Prevention, 2010; Lanou, Berkow, & Barnard., 2005; Larson et al., 2009; Wallace, 2002). This was particularly true for female adolescents and young adults who reportedly had the lowest calcium intake compared to recommendations (Centers for Disease Control and Prevention, 2010; Larson et al., 2009). One study completed by Larson et al. found that females consumed approximately 860 mg and males consumed 1052 mg on average during young adulthood. The trends discovered in the Bogalusa Heart study and other epidemiological studies suggest that more nutritious drinks such as milk and fruit juices are being replaced by soft drinks and other sweetened beverages. The study highlighted that mean gram consumption of milk significantly decreased whereas mean gram consumption of sweetened beverages increased (Nicklas, 2003).

Minimal studies have examined calcium intake during the college years. However, a longitudinal study completed by Larson et al. (2009) found that the transition
period between adolescence and young adulthood to be critical for diary and calcium intake in that both absolute intake and density intake decrease. On average, daily calcium intakes reduced by $153 \pm 19$ mg and $194 \pm 23$ mg in females and males respectively. In addition, overall more than 72% of females and 55% of males consumed less than the Adequate Intake (AI) levels for calcium (Larson et al., 2009). A survey that examined both calcium intake in upper-division college women found a broad range of calcium intake and that most women consumed less than the recommended 1200 mg per day and the lowest 25% consumed approximately half of the recommendation on a daily basis. The survey also indicated that women who consumed little dairy products were significantly less likely to meet the recommended guidelines for calcium (Wallace, 2002). Therefore, students with lactose intolerance that avoid milk and dairy products, will further reduce calcium consumption thus increasing their risk for inadequate PBM and thus osteoporosis; making college-aged individuals with lactose intolerance a population that may be at risk.
CHAPTER III

METHODOLOGY

Research Design

The purpose of this study was to evaluate the differences in dietary calcium intake of those with lactose intolerance compared to those without in college students. The participants were college-aged students, including both undergraduate and graduate, between the ages of 18 and 30 at Kent State University in Kent, Ohio. Inclusion criteria included full- and part-time undergraduate and graduate students of Kent State University both with and without lactose intolerance. Lactose intolerance was self-disclosed by the participants. In the survey, the participants who stated that they have lactose intolerance specified how they were diagnosed: self, doctor, or doctor with test. Exclusion criteria included those not enrolled at Kent State University or did not meet the age requirement. Individuals who participated in the survey were entered in a drawing for a $25.00 gift card for Starbucks. Of the 2,711 students who responded, 1,724 met the criterion and were included in data analysis. There were 1,531 participants who stated that they did not have lactose intolerance, 193 with self-disclosed lactose intolerance.

Survey Administration

Following the approval of the Kent State University’s Institutional Review Board (IRB), the questionnaire was administered through the online instrument of Qualtrics. After receiving IRB consent, approval was obtain from the Office of the University Registrar, which allowed from the distribution of the survey to Kent State students via email contact. The email contained a cover letter explaining the format and
confidentiality of the study. An electronic consent form containing the procedure and the contact information of the researcher and Kent State University’s IRB were provided at the beginning of the survey. The survey was open for four weeks with reminder emails sent at the beginning of the second and third week.

**Survey Questionnaire**

Six sections were involved in the survey. Questions from the survey are modeled from questions asked on the Harvard Youth and Adolescence Questionnaire, the University of Minnesota Project-EAT survey, and the most commonly eaten foods from the Report of the Dietary Guidelines Advisory Committee on the Dietary Guidelines for Americans (2010). A compiled list of all foods utilized in the survey along with their corresponding calcium, in milligrams, per serving can be found in Appendix C. Part I of the survey included demographic questions including age, class status, gender, ethnicity, height/weight, living location, and meal plan status. If the participant did not meet the criteria and was 31 years of age or older, the survey was terminated. However, if the participant did meet the age criteria, they answered a total of seven questions during the demographic section. Part II of the survey focused on lactose intolerance. These questions were used to determine lactose intolerance and related behaviors. If the individual did not have lactose intolerance, they continued to the next section of questions regarding their milk and dairy intake. If the individual did state, however, that they have lactose intolerance, they had the potential to answer a maximum of 11 questions. The third part of the survey focused on common dairy foods that are consumed in the participant’s diet. Depending on their answers, participants had the
potential to answer a minimum of 22 questions and a maximum of 43 questions. Part IV focused on non-dairy food sources that are notably high in calcium. In this section, participants had the potential to answer a minimum of 19 questions and a maximum of 38 questions. Part V focused on fortified foods choices such as breakfast cereals and bars, juices, and so forth. Depending on their answers, participants had the potential to answer a minimum of five questions and a maximum of 12 questions. Finally, part VI focused on supplement usage to determine any supplemental calcium that was consumed outside of food consumption. In this section, participants had the potential to answer a minimum of one question and a maximum of eight questions. It was estimated that the completion of all questions in the survey would take approximately 15-25 minutes.

**Analysis**

Analysis of the results was conducted to determine significance following the four weeks of data collection. Consultations from Kent State University statisticians were utilized throughout the survey design, data collection, and analysis process. Demographic data including age, class status, gender, ethnicity, weight/height, living arrangements, and the use of a meal plan were analyzed by using descriptive statistics (i.e., frequency distribution and mean). Additional descriptive statistics (i.e., frequency and mean) were run on the questions only answered by those with lactose intolerance; “Do you have lactose intolerance?” “How were you diagnosed?” “Did you receive any dietary management or education regarding lactose intolerance?” “Where or from whom did you receive dietary management or education regarding lactose intolerance?” “Have you ever purposefully avoided milk or other dairy products?” “Do you consume
calcium-fortified foods to compensate for limiting dairy products?” “Do you consume Lactaid?” and “Do you consume a lactase enzyme pill?”

A one-way ANOVA was used to compare the self and doctor diagnosed lactose intolerance groups to the control group for total calcium intake, and calcium intakes from milk, dairy, nondairy foods and beverages and supplements. Statistical significance was found in the one-way ANOVA, therefore two lactose intolerance groups were collapsed and a post-hoc analysis was conducted to seek significance between the lactose intolerant group and the control group. Statistical significance was set a priori at \( p \leq 0.05 \) and was conducted using Statistical Package for the Social Sciences (version 20, 2012, SPSS Inc. Chicago, IL).
CHAPTER IV

RESULTS

The purpose of this study was to evaluate the differences in total calcium intake and calcium intake from milk and dairy products, non-dairy sources, and supplements of those with lactose intolerance compared to those without in college students. Of the 22,748 electronic questionnaires administered, 2,711 questionnaires were attempted (11.9% response rate). There were a total of 1,724 participants that entered statistical analysis (7.5% response rate). There were 987 eliminated from statistical analysis due to numerous reasons, 24 participants did not consent to take the survey, 228 did not meet the age requirements (>31 years), 445 did not answer all of the questions completely, 185 answered “unsure” for whether or not they had lactose intolerance, and 105 were eliminated for reporting unrealistic consumption of calcium above 2500 milligrams (mg) per day.

Among the 1,724 participants who entered statistical analysis, 193 participants self-disclosed that they were lactose intolerant and 1,531 participants stated that they were not lactose intolerant. Of the 193 with lactose intolerance, 86 stated they were self-diagnosed (LI-self), and 107 reported they were diagnosed by a medical doctor (LI-MD). Table 9 describes the general demographic characteristics of participants.
Table 9

General Characteristics of Participants

<table>
<thead>
<tr>
<th></th>
<th>LI-self n (%)</th>
<th>LI-MD n (%)</th>
<th>Control n (%)</th>
<th>Total n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-21</td>
<td>52 (60.5)</td>
<td>62 (57.9)</td>
<td>965 (63)</td>
<td>1079 (62.6)</td>
</tr>
<tr>
<td>22-25</td>
<td>22 (25.6)</td>
<td>36 (33.6)</td>
<td>437 (28.5)</td>
<td>495 (32.3)</td>
</tr>
<tr>
<td>26-29</td>
<td>12 (14)</td>
<td>9 (8.4)</td>
<td>129 (8.4)</td>
<td>150 (8.7)</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>18 (20.9)</td>
<td>14 (13.1)</td>
<td>323 (21.1)</td>
<td>355 (20.6)</td>
</tr>
<tr>
<td>Female</td>
<td>68 (79.1)</td>
<td>93 (86.9)</td>
<td>1208 (78.9)</td>
<td>1396 (80.9)</td>
</tr>
<tr>
<td><strong>Class standing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Undergrad</td>
<td>64 (74.4)</td>
<td>91 (85)</td>
<td>1267 (82.8)</td>
<td>1422 (82.5)</td>
</tr>
<tr>
<td>Graduate</td>
<td>22 (25.6)</td>
<td>16 (15)</td>
<td>264 (17.2)</td>
<td>302 (17.5)</td>
</tr>
<tr>
<td><strong>Race/ethnicity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>69 (80.2)</td>
<td>87 (81.3)</td>
<td>1306 (85.3)</td>
<td>1462 (84.8)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>2 (2.3)</td>
<td>6 (5.6)</td>
<td>37 (2.4)</td>
<td>45 (2.6)</td>
</tr>
<tr>
<td>African American</td>
<td>8 (9.3)</td>
<td>5 (4.7)</td>
<td>55 (3.6)</td>
<td>68 (3.9)</td>
</tr>
<tr>
<td>Asian</td>
<td>4 (4.7)</td>
<td>3 (2.8)</td>
<td>69 (4.5)</td>
<td>76 (4.4)</td>
</tr>
<tr>
<td>Native American</td>
<td>0 (0)</td>
<td>1 (0.9)</td>
<td>3 (0.02)</td>
<td>4 (0.02)</td>
</tr>
<tr>
<td>Other</td>
<td>1 (1.2)</td>
<td>3 (2.8)</td>
<td>19 (1.2)</td>
<td>23 (1.3)</td>
</tr>
<tr>
<td>Refused to answer</td>
<td>0 (0)</td>
<td>1 (0.9)</td>
<td>16 (1.1)</td>
<td>17 (0.1)</td>
</tr>
<tr>
<td>Mixed race</td>
<td>2 (2.3)</td>
<td>1 (0.9)</td>
<td>26 (1.7)</td>
<td>29 (1.7)</td>
</tr>
<tr>
<td><strong>Residency</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On-campus</td>
<td>22 (25.6)</td>
<td>32 (29.9)</td>
<td>518 (33.8)</td>
<td>572 (33.2)</td>
</tr>
<tr>
<td>Off-campus</td>
<td>64 (27.9)</td>
<td>75 (70.1)</td>
<td>1013 (66.2)</td>
<td>1152 (66.8)</td>
</tr>
<tr>
<td><strong>Meal plan</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>25 (29.1)</td>
<td>37 (34.6)</td>
<td>518 (33.8)</td>
<td>580 (33.6)</td>
</tr>
<tr>
<td>No</td>
<td>61 (70.9)</td>
<td>70 (65.4)</td>
<td>1013 (66.2)</td>
<td>1144 (66.4)</td>
</tr>
</tbody>
</table>

A one-way ANOVA analysis was performed to compare total calcium intake and calcium intake from milk and dairy products, non-dairy sources, and supplements between three groups: LI-self group, LI-MD group, and control group. The results are presented in Table 10. Post-hoc analysis revealed that there was statistical significance found between the LI-groups and the control ($p \leq 0.001$).
Table 10

*Average Daily Calcium Intake (Mean ± Standard Deviation) From Milk and Dairy Sources, Non-Dairy Sources, Supplemental Sources, and Total From All Sources in the Self-Diagnosed Lactose Intolerant (LI-Self), Doctor-Diagnosed Lactose Intolerant (LI-MD), and Control Groups*

<table>
<thead>
<tr>
<th>Calcium intakes (mg)</th>
<th>LI-self</th>
<th>LI-MD</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total daily calcium</td>
<td>936.02 (+503.54)</td>
<td>894.40 (+486.96)</td>
<td>1039.41 (+529.35)^a</td>
</tr>
<tr>
<td>Milk and dairy sources</td>
<td>501.90 (+362.48)</td>
<td>445.29 (+374.04)</td>
<td>721.66 (+440.02)^b</td>
</tr>
<tr>
<td>Non-dairy sources</td>
<td>253.25 (+186.13)</td>
<td>263.32 (+205.27)</td>
<td>207.63 (+169.75)^cd</td>
</tr>
<tr>
<td>Supplements</td>
<td>180.87 (+278.35)</td>
<td>185.79 (+280.11)</td>
<td>110.12 (+228.88)^cd</td>
</tr>
</tbody>
</table>

^a = p < 0.05 versus LI-MD  
^b = p < 0.001 versus LI-self and LI-MD  
^c = p < 0.05 versus LI-self  
^d = p < 0.005 versus LI-MD

There was no statistical significance between the LI-self group and LI-MD group in total calcium intake and calcium from milk and dairy products, non-dairy sources, and supplements. A total intake of calcium from all sources was statistically higher in control group compared to the LI-MD group. According to the DRI (Dietary Reference Intake), the calcium recommendation for this age group and for both genders is 1000 mg/day (National Institutes of Health: Office of Dietary Supplements, 2012). The mean intake of calcium for the LI-self group was 93.6% of the DRI, and the LI-MD group consumed 89.44% of the DRI. The control group consumed an average of 1039.41± 526.84 mg/day, which is 103.94% of the DRI.
For calcium intake from milk and dairy products, the LI-self group \((p \leq 0.001)\) and LI-MD group \((p \leq 0.001)\) consumed significantly less calcium compared to the control group. On average, 53.6% of total calcium intake came from milk and dairy products from the LI-self group, 49.8% for the LI-MD group, and 69.4% for the control group. Calcium intake from non-dairy sources was statistically higher in the control group compared to the LI-self \((p = 0.046)\) and LI-MD \((p = 0.004)\) groups, respectively. On average, 27.1% of total calcium intake came from non-dairy products for the LI-self group, 29.4% for the LI-MD group, and 20% for the control group.

A total of 806 participants responded that they consumed some sort of supplement; 243 participants stated they consumed a supplement with calcium. Of the LI-self group, 28 (32.56%) and of the LI-MD group 29 (27.10%) consumed a supplement with calcium. There were 161 (10.51%) in the control group that consumed a supplement with calcium. There was a statistical significance between the control group and LI-self group \((p = 0.018)\) and LI-MD group \((p = 0.004)\). On average, 19.3% of total calcium intake came from supplementation from the LI-self group, 20.8% for the LI-MD group, and 10.6% for the control group.

While completing questionnaires, individuals who reported that they had lactose intolerance were directed to answer additional questions. There were 178 (92%) participants who stated that they have purposefully avoided milk or other dairy products. Of the 178 participants who have avoided milk or dairy products, 100 (56%) stated that they consumed calcium-fortified foods to compensate for limiting milk and dairy products, whereas, 60 (34%) responded no, and 18 (10%) said they were unsure. An
additional question that the participants with lactose intolerance answered was whether or not they consume Lactaid; 72 (37%) stated *yes*, 108 (56%) stated *no*, and 13 (7%) stated *unsure*. Individuals with lactose intolerance were also asked if they consume a lactase enzyme pill; 50 (26%) responded *yes*, 136 (70%) responded *no*, and 7 (4%) responded *unsure*. There were 33 participants that consumed both Lactaid and an lactase enzyme.

Individuals with lactose intolerance were also asked the question: “Did you receive any dietary management or education regarding lactose intolerance?” Seventy-two participants (37.3%) responded that they have received nutrition education for their lactose intolerance; they were able to chose one or more of the following: doctor (MD), registered dietitian (RD), registered nurse (RN), books, magazines, Internet, television, friends/family, or other. Of the 86 participants of the self-diagnosed group, 18 (20.93%) responded that they have received nutrition education or management for their lactose intolerance; whereas, 53 (49.53%) of the 107 individuals who were doctor diagnosed, responded that they have received nutrition education or management for their lactose intolerance.

The top three responses for where the individuals consumed their nutrition education for lactose intolerance in both the LI-self and LI-MD groups were:

1. Doctor: 52 responses (72.2%)
2. Internet: 36 responses (50%)
3. Friends/family: 34 responses (47.2%)

For the LI-self group, the top three responses were

1. Friends/family: 12 responses (66.7%)
2. Internet: 11 responses (61.1%)
3. Books: 7 responses (38.9%)

For the LI-MD group, the top three responses for nutrition education sources were:

1. Doctor: 47 responses (88.7%)
2. Internet: 25 responses (47.2%)
3. Friends/family: 22 responses (41.5%)
CHAPTER V
DISCUSSION

The purpose of this study was to evaluate the differences in dietary calcium intake of those with lactose intolerance compared to those without in college students. The hypotheses of the current study were accepted; individuals with lactose intolerance compared to those without consumed a different amount of calcium and a different amount of milk and dairy products.

The primary constituent for the skeletal system is calcium and ample calcium consumption is essential for skeletal growth and development (J. Brown, 2008; National Institutes of Health: Office of Dietary Supplements, 2012). Numerous studies have been conducted on children, adolescents, and postmenopausal women with respect to calcium intake and skeletal health, showing suboptimal intake of calcium at any age can cause low bone density, and an increased fracture risk (Bonjour et al., 1994; Boot et al., 2010; Clark, 2008; Rizzoli et al., 2009). Specifically, it is well established that sufficient calcium intake during adolescence and through age 30, an important window to attain peak bone mass, is critical in prevention of osteoporosis later in life (J. Brown, 2008; Larson et al., 2009; Nicklas, 2003).

People who have lactose intolerance cannot metabolize lactose properly and as a result, they experience unpleasant gastrointestinal symptoms including cramping, bloating, and diarrhea after consuming lactose-containing foods such as milk and dairy products. Therefore, individuals with lactose intolerance have notably been a population with minimal milk and dairy consumption and consequently inadequate calcium intake.
and bone development (Heyman, 2006; Jarvis & Miller, 2002; Lomer et al., 2008; Kull et al., 2009; Nicklas, 2003). Lactose intolerance may first appear in teenage and young adulthood (college-aged). College students are overall at risk for inadequate calcium intake as well as low intake of other nutrients such as fiber, iron, and folate (Ha & Caine-Bish, 2009; Haberman & Luffey, 1998). Furthermore, college students with lactose intolerance are at an even greater risk of inadequate calcium intake and osteoporosis later in life.

In the present study, the LI-MD group had significantly less total calcium compared to the control group, consuming 86% total calcium of the control group. College-aged individuals fall in the latter part of the skeletal development window, and in spite of the importance of optimal calcium intake during the college years, there have been few studies on this age group investigating calcium intake of those with lactose intolerance. However, the results of the current study was in accordance with observations from other studies that examined adolescences, adults, and post-menopausal women to compare calcium intake with individuals with lactose intolerance (Kull et al., 2009; Matlik et al., 2007). For example, Matlik et al. reported that in 246, 10 to 13 year old adolescent females who were either diagnosed or perceived lactose intolerant consumed significantly less total calcium and had lower spinal bone mineral content values.

Dissimilar to previous studies, however, was that the control group in the current study met the daily recommendations for calcium. A longitudinal study completed by Larson et al. (2009) discovered that not only did 72% of females and 55% of males
consume less than the Adequate Intake (AI) levels for calcium, but also that the transitional period from adolescence to young adulthood was a time absolute calcium intake decreased. Another study found that the calcium intake in upper-division college women did not meet the daily calcium recommendations and that the lowest 25% of subjects consumed approximately half of the recommendations (Wallace, 2002).

The discrepancy between the results of the present study to past research could possibly be due to differences in methodology. Studies have demonstrated that although food frequency questionnaires (FFQ) are convenient, they tend to overestimate typical intake (Bingham et al., 1994; Day, McKeown, Wong, Welch, & Bingham, 2001). For example, a study completed by Day et al. (2001) found that a FFQ overestimated the means of nitrogen, potassium and sodium compared to a seven-day food diary. The current study utilized a FFQ and could therefore account for the above average calcium intake from the control group compared to previous research (Bingham et al., 1994; Day et al., 2001). An additional explanation for why the present study’s results were not consistent with the above Larson et al. (2009) study, is that the present study examined all sources of calcium including non-dairy sources, whereas Larson et al. strictly looked at milk and dairy products in their analysis.

Based on former studies that demonstrated low milk and dairy intake in those with lactose intolerance, it was not surprising that in the present study, of the 193 self- and doctor-diagnosed lactose intolerant groups, the majority (92%) of them responded that they have avoided milk or dairy products (Kull et al., 2009; Matlik et al., 2007). This result shows that the aversion to milk and dairy products in individuals with
lactose intolerance were evident. Past research stated that typically, individuals who do not have lactose intolerance consume 70% of their dietary calcium from milk and dairy products (Levenson & Bockman, 1994). The control group in the current study was uniform to previous research in that 69.4% of the control group’s calcium was derived from milk and dairy products. Whereas, reflecting avoidance of milk and dairy products in lactose intolerant groups, the current study found that the LI-self group consumed on average 53.6% of calcium from milk and dairy products, the LI-MD group consumed 49.8%.

A study completed by Kull et al. (2009) found comparable results as the current investigation; the researchers found that in participants who had self-diagnosed lactose intolerance showed a significant self-imposed reduction in milk consumption, increased bone turnover, and thus an increased fracture risk. The results from the current study, along with other research, such as from Matlik et al. (2007) and Kull et al. (2009), reinforced that individuals who avoid milk and dairy products ingest less than the recommended amounts of calcium. In addition to the avoidance of milk and dairy, research conducted by Nicklas (2003) found that individuals with suboptimal lactase activity, like those with lactose intolerance, were only able to absorb 25% to 58% of milk’s lactose; whereas, individuals with adequate lactase activity were able to absorb 92%. This emphasizes that those with lactose intolerance may absorb a lower amount of calcium from milk and dairy products and that the total dairy calcium intake may in fact be even lower in the LI-groups. Based on these research results, although this present study did not evaluate bone density or fracture risk, it can be postulated that the
participants in the present study may have an increased risk for fracture in the future if their calcium intake stays at its current suboptimal level.

Notwithstanding, milk and dairy intake are the preferred source for calcium because the bioavailability of milk and dairy products amasses their non-dairy counterparts. The calcium from milk and dairy products is readily absorbed, resulting in increased bone mineral content (Bronner & Pansu, 1999; Devine et al., 1996; Gueguen & Pointillart, 2000; Heaney, 2000; Kalkwarf et al., 2003; Linus Pauling Institute, 2010; Nicklas, 2009). Unfortunately, as seen in the present study, those with lactose intolerance are characterized as avoiding milk and other dairy products (Heyman, 2006; Jarvis & Miller, 2002; Kull et al., 2009; Lomer et al., 2008; Nicklas, 2003). When individuals abstain from milk and dairy products, fortified foods, non-dairy sources high in calcium, supplemental calcium sources, and other management techniques are encouraged to meet recommended calcium intake (Devine et al., 1996; Heaney, 2000; Nicklas et al., 2009).

There are therapeutic techniques such as the use of products that allow milk and dairy products to be tolerated; these products include enzyme tablets or drops such as Dairy Ease, Lactaid, and so forth. Similarly, there are various products that have lactase added to the product to aid in tolerance (Lomer et al., 2008; Nelms et al., 2007; Onwulata et al., 1989). However, only 37% used Lactaid and 26% used a lactase enzyme. In the current study, lactose intolerant groups had higher calcium intake from non-dairy calcium sources and supplements compared to their control counterparts, which perhaps shows that lactose intolerant participants acknowledged their risk for low calcium intake and
consequent reduce bone density. It is noteworthy that the LI-groups still did not reach the DRI for calcium despite of higher consumption of calcium from non-dairy and supplemental sources compared to control group that had higher calcium intake from milk and dairy products. The LI-self consumed 46.38% and the LI-MD consumed 50.32% of their daily calcium from non-dairy and supplemental sources; compared to the control group whom consumed 30.57% from non-dairy and supplemental sources. This finding may highlight the importance of milk and dairy products as primary sources of calcium.

As previously mentioned, the bioavailability of non-dairy products is not as high as dairy products. Although some plant foods such as spinach and rhubarb may appear to be substantial sources of calcium, the presence of oxalic acid and phytic acids in those foods inhibit calcium absorption and thus a greater amount must be consumed in order to achieve the same absorbability as an eight-ounce glass of milk. In addition, non-dairy sources are lacking vitamin D, which aids in calcium absorption (Dawson-Hughes et al., 1997; Dawson-Hughes et al., 1987; Gennari, 2001). For example, an individual would need to consume 16.3, ½ cup servings of cooked spinach in order to achieve the same amount of calcium absorbed as one-eight ounce glass of milk. Accordingly, intake from non-dairy sources does not necessarily reflect the true intake or absorption of calcium for these groups; and their calcium may in fact be less than what was reported (Guegen & Pointillart, 2000; Levenson & Bockman, 1994; Linus Pauling Institute, 2010; National Institutes of Health: Office of Dietary Supplements, 2012).
Another significant result from the current study was that calcium intake of the LI-self group did not differ from that of the LI-MD group in all categories of calcium sources: milk/daily products, non-dairy calcium sources, calcium supplement, and overall daily calcium intake. It would be deduced that those that were doctor-diagnosed would have higher calcium intakes than self-diagnosed lactose intolerant individuals receiving nutritional education for lactose intolerance management. Yet the results of the present study observed that of the 193 individuals who stated that they had lactose intolerance, only 37.3% of them declared that they had received any education pertaining to lactose intolerance. More importantly, the LI-MD group had more participants that had received nutrition education (LI-MD 49.53% vs. LI-self 20.93%), and yet there were no significant differences between milk and dairy products and total calcium intake between the LI-self and LI-MD groups. This finding suggests that nutrition information that they received was not effective enough to change their calcium intake through neither milk/dairy products nor other sources of calcium including supplements.

Of the 72 in the lactose intolerant group that stated they received nutrition education, 72.2% stated that they received education from doctors. Fifty percent stated they have received some of their education from the Internet and 47.2% from friends and family. Unfortunately, only 19.4% of those with lactose intolerance responded that they received any education from a Registered Dietitian. It is evident from the results of the current study that the nutrition education given by the physicians regarding lactose intolerances did not translate into higher calcium intake. Also, the two second-most avenues of information were from the Internet and friends and family, rather than other
health professionals such as registered dietitians whom are the nutrition experts and therefore individuals are self-educating and are not receiving individualized treatment for their lactose intolerance.

**Strengths**

There are many strengths in this study. The survey was confidential and no identifying factors were asked. The online survey allowed individuals to take the survey at their own pace and to be taken in privacy to promote honest answers. In addition, the survey was administered online and was therefore able to reach a large number of population. The survey was based on the Harvard Youth and Adolescence Questionnaire, the University of Minnesota Project-EAT survey, and the most commonly ate calcium foods from the Report of the Dietary Guidelines Advisory Committee on the Dietary Guidelines for Americans (2010). The participants went through rigorous screening to improve content validity; this is why so many participants were eliminated from statistical analysis.

**Limitations**

This study does not come without limitations. First of all, the study had to rely on honesty in self-reporting of lactose intolerance and typical diet pattern. Participants self-disclosed their lactose intolerance diagnosis and there were no validation tests used such as a hydrogen breath test. The current study utilized a food frequency questionnaire to determine calcium intake and therefore participants may have overestimated their intake (Bingham et al., 1994; Day et al., 2001). Individuals taking the survey may have incorrectly estimated their intake based on their own portion size perception. The survey
participants were primarily Caucasian females with a low-male response rate. Although convenient, past research have found that college females tend to respond to Web surveys at higher rates compared to men (Underwood, Kim, & Matier, 2000).

The survey was administered online; therefore, there was not an interviewer present to clarify questions, answers, or portion sizes for the food items. For example, of the 1,909 subjects that met the requirements, 183 participants responded *unsure* for the “Do you have lactose intolerance or lactose malabsorption” question. It is impossible to translate the *unsure* responses; it could mean that the participant was not sure whether or not they have lactose intolerance, or simply these individuals were not sure what the term *lactose intolerance* meant.

As stated earlier, the bioavailability of foods varies. Non-dairy foods in particular are not absorbed as efficiently as dairy products; therefore actual calcium absorption does not match total intake. Finally, levels of calcium for food items were estimations; realistically, calcium content is not homogenous across brands (i.e., yogurts have varying amounts of calcium). Hence, all reported calcium intakes are estimations based on a typical concentration of calcium in the varying food products.

Although calcium intake is critical for bone development, there are numerous other factors that influence bone development. Factors such as hereditary, gender, ethnicity, physical activity, dietary habits, lifestyle, and vitamin D intake all influences bone mass (Bonjour et al., 1994; Centers for Disease and Prevention, 2010; Haskell et al., 2007; Kalkwarf et al., 2003; Krall & Dawson-Hughes, 1993; Ma et al., 2007; Matvkovic et al., 1990; Megyesi et al., 2011; Ralston & Uitterlinden, 2010; Sigurdsson et al., 2008).
This study only examined calcium intake and, therefore, it is important to note that even though calcium intake is critical, there are other factors that can result in osteoporosis later in life.

**Applications**

The results of this study provide direction for the development of nutritional interventions for individuals with lactose intolerance to ensure adequate calcium intake. The lack of statistical differences between the LI-self and LI-MD groups sparks concern of relaying sufficient information from health professional to patient regarding lactose intolerance and calcium intake. This should be explored especially since only 19.4% of participants with lactose intolerance reported obtaining their nutrition information for lactose intolerance from registered dietitians, the nutrition experts. Besides physicians, the LI-groups consistently reported non-health professional sources such as the Internet, friends and family, and books as information sources regarding lactose intolerance management. These results assume that a large amount of LI-individuals are self-educating, which is of concern because the information that they are receiving may not have been screened nor evaluated for their accuracy.

Registered dietitians (RD) can use this information to increase their presence for nutritional interventions in order to prevent inadequate calcium intake in college-aged individuals with lactose intolerance. The Academy of Nutrition and Dietetics recommend experimenting with small amounts of lactose-containing foods and gradually increasing to determine an individual’s tolerance level as tolerance for dairy foods can vary for individuals (Academy of Nutrition and Dietetics; 2011; Heyman, 2006; Nicklas,
2003). For example, cheeses and cultured-containing dairy foods are better tolerated than milk but still are ample sources of calcium (Jarvis & Miller, 2002; Lomer et al., 2008; Nelms et al., 2007). Providing individualized screening to determine the degree of lactose tolerance can also allow RDs to educate students on foods that can be tolerated to improve calcium intake. An individualized plan created between an RD and the individual could be beneficial in improving calcium intake.

Furthermore, RDs can reach greater amount of patients through the encouragement of referrals by physicians. However, there is concern of the presence of RDs in the medical field. Currently, most insurance companies do not pay for a RD consult for the management of lactose intolerance. Registered dietitians need to help create a public policy that allows individuals to receive consultation for lactose intolerance management and to potentially prevent a public health concern.

Registered dietitians need to identify barriers for optimal calcium intake in college students with lactose intolerance and seek ways to overcome suboptimal calcium intake (McCory et al., 1999; Nielsen et al., 2002). Based on the education sources in this study, RDs can utilize the Internet and Internet-based social media platforms to further reach this population. In addition, food services can work to create more products that would appeal to the college population. As a result, this can increase access and likeness to lactose free milk and other dairy products and enzyme pills could improve calcium intake.
**Future Research**

The results of the current study inspire future research. There have been minimal studies on college-aged students regarding lactose intolerance and calcium intake. Ergo, additional research on this population will greatly improve the current literature. In addition, exploring calcium intake along with bone mineral density in college-aged individuals will give better insight for future osteoporosis risk. The sample population from the current study is predominately White, Caucasian females. Future research involving a more detailed look into demographical effects, such as socioeconomic status, gender, age of diagnoses, race/ethnicity, and so forth, is warranted to examine any connections between calcium intake and lactose intolerance. Exploring bioavailability and absorption of foods and bone mass would also further advance current literature regarding the importance of calcium consumption and would benefit those that struggle with milk and dairy consumption.

There were 185 participants who were eliminated from statistical analysis because they answered *unsure* for whether or not they have lactose intolerance. It can be assumed that these individuals were not sure if they have lactose intolerance. Future research in this population is warranted because this group had the lowest intake of calcium between all the groups with 862.2 mg per day.

In particular, future studies need to be conducted between the LI-self and LI-MD diagnosed groups and their calcium intake to explore a detachment in education for those with lactose intolerance. Determining if and what current recommendations that are being made by physicians are also an area for future research. This is important to
determine if there also needs to be education for health professionals, in that some health professionals may believe that complete avoidance of milk and dairy is necessary for treatment of lactose intolerance (Marchiondo, 2009).

**Conclusion**

The study revealed that individuals of the doctor-diagnosed lactose intolerance group consumed less total calcium compared to the control group. Both of the lactose-intolerant groups consumed less calcium from milk and dairy sources compared to their non-lactose intolerant counterparts. Individuals with lactose intolerance consumed more calcium from non-dairy sources and supplements, although, it was not enough calcium to reach the daily recommendations of calcium. There were no differences between the self-diagnosed and the doctor-diagnosed lactose intolerant groups across all categories: milk and dairy consumption, non-dairy calcium sources, calcium supplements, and total calcium intake.
APPENDICES
APPENDIX A

STUDY CONSENT FORM
Appendix A
Study Consent Form

Informed Consent to Participate in a Research Study

**Study Title:** Comparison of dietary calcium intake of college-aged individuals with lactose intolerance to those without

**Principal Investigator:** Amanda Buchner

You are being invited to participate in a research study. This consent form will provide you with information on the research project, what you will need to do, and the associated risks and benefits of the research. Your participation is voluntary. Please read this form carefully. It is important that you ask questions and fully understand the research in order to make an informed decision. Please keep a copy of this for your records.

**Purpose:** The purpose of this study is to evaluate the differences in dietary calcium, milk, and dairy product intake of those with lactose intolerance compared to those without in college students.

**Procedures**
In order to participate in this study, it is required to be enrolled in Kent State University, full- or part-time, and to fall into the 18-30 year old age range. Participation of this survey involves completing a questionnaire regarding your typical eating habits. The survey should take anywhere between 15-25 minutes. The data being collected will include demographic information, questions regarding lactose intolerance, followed by typical eating behaviors and food choices.

**Benefits**
The benefits to society is that this research will bring include understanding any connection to lactose intolerance, calcium and dairy intake, and college-aged individuals and if further interventions that may be warranted. On a larger scale, your answers will bring attention to potential calcium deficiencies present during the college-years that can aid in prevention of osteoporosis later in adulthood. This study will also examine if there needs to be a particular focus on sub-populations (i.e., lactose intolerance) for calcium deficiencies.
Risks and Discomforts
You may feel uncomfortable providing information on the food items that you consume on a daily, weekly, or monthly basis. Please remember that you are not being judged or tested and it is critical that you answer the questions honestly. This questionnaire is completely confidential and your name will not be associated with any of the results. Your participation is voluntary and you can stop anytime during the survey if you wish to.

Study title: Comparison of dietary calcium intake of college-aged individuals with lactose intolerance to those without.

Privacy and Confidentiality
Your study related information will be kept confidential within the limits of the law. No identifying information will be collected. Research participants will not be identified in any publication or presentation of research results; only aggregate data will be used.

Compensation
A potential compensation to the participants in this study will be a $25.00 gift card to the Kent State University bookstore. Upon completion of the survey, you may provide your email address to enter to win the gift card.

Voluntary Participation
Taking part in this research study is entirely up to you. You may choose not to participate or you may discontinue your participation at any time without penalty or loss of benefits to which you are otherwise entitled. You will be informed of any new, relevant information that may affect your health, welfare, or willingness to continue your study participation.

Contact Information
If you have any questions or concerns about this research, you may contact Amanda Buchner at abuchner@kent.edu or Dr. Eun-Jeong Ha at eha@kent.edu This thesis has been approved by the Kent State University Institutional Review Board. If you have any questions about your rights as a research participant or complaints about the research, you may call the IRB at 330.672.2704.

Consent Statement and Signature
My completion and return of this survey questionnaire will be indicative of my consent to participate in this research study. I may print a copy of this consent statement for future reference.
APPENDIX B

SURVEY QUESTIONNAIRE
Appendix B

Survey Questionnaire

Part I: Demographic Questions
1. What is your age?
   a. 18-19  b. 20-21  c. 22-23  d. 24-25  e. 26-27  f. 28-30  g. 31 or older
2. What is your class status?
   a. Undergraduate  
   b. Graduate
3. Gender
   a. Male
   b. Female
4. Race/ethnicity
   a. Caucasian
   b. Hispanic
   c. African American
   d. Asian
   e. Native American
   f. Other
   g. Choose not to answer
5. Height
6. Weight
7. Where do you live?
   a. On-campus
   b. Off-campus
8. Do you have an on-campus meal plan?
   a. Yes
   b. No

Part II: Lactose-Intolerance Questions
1. Do you have lactose intolerance or lactose malabsorption?
   a. Yes
   b. No
   c. Unsure
2. At what age were you diagnosed?: _____
3. How were you diagnosed?
   a. Self
   b. Doctor
   c. Doctor with test (Hydrogen breath test)
4. Does anyone in your family have lactose intolerance or lactose malabsorption?
   a. Yes
   b. No
   c. Unsure
5. Who in your family has lactose intolerance or lactose malabsorption?
   a. Parent
   b. Sibling
   c. Other: _____
6. Did you receive any dietary management or education regarding lactose intolerance?
   a. Yes
   b. No

7. Where or from whom did you receive dietary management or education regarding lactose intolerance?
   a. Doctor
   b. Registered Dietitian
   c. Nursing staff
   d. Books
   e. Magazines
   f. Internet
   g. TV
   h. Friends or family
   i. Other: ___

8. Have you every purposefully avoided milk or other dairy products?
   a. Yes
   b. No

9. Do you consume calcium-fortified foods to compensate for limiting dairy products?
   a. Yes
   b. No
   c. Unsure

10. Do you consume Lactaid in order to consume milk or other dairy products?
    a. Yes
    b. No
    c. Unsure

11. Do you consume a lactase enzyme pill in order to consume milk or other dairy products?
    a. Yes
    b. No
    c. Unsure

Part III: Milk and Dairy Consumption
Milk Products

How often do you consume the following items:

1. How often do you consume white milk, glass or with cereal or oatmeal (NOT SOYMILK, ALMOND MILK, OR RICE MILK)?
   a. Daily
   b. Weekly
   c. Monthly
   d. Never

2. How many 1 CUP servings of white milk (NOT SOYMILK, ALMOND MILK, OR RICE MILK), glass or with cereal or oatmeal, do you consume per day?
   a. 1 b. 2 c. 3 d. 4 e. 5 f. 6 g. 7 h. 8 i. 9 j. 10 or more

3. How many 1 CUP servings of white milk (NOT SOYMILK, ALMOND MILK, OR RICE MILK), glass or with cereal or oatmeal, do you consume per week?
   a. 1 b. 2 c. 3 d. 4 e. 5 f. 6 g. 7 h. 8 i. 9 j. 10 or more

4. How many 1 CUP servings of white milk (NOT SOYMILK, ALMOND MILK, OR RICE MILK), glass or with cereal or oatmeal, do you consume per month?
   a. 1 b. 2 c. 3 d. 4 e. 5 f. 6 g. 7 h. 8 i. 9 j. 10 or more

5. How often do you consume white soymilk, glass or with cereal or oatmeal?
   a. Daily
   b. Weekly
6. How many 1 CUP servings of white soymilk, glass or with cereal or oatmeal do you consume per day?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
7. How many 1 CUP servings of white soymilk, glass or with cereal or oatmeal do you consume per week?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
8. How many 1 CUP servings of white soymilk, glass or with cereal or oatmeal do you consume per month?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
9. How often do you consume chocolate or other flavored milk, glass or with cereal or oatmeal (NOT SOYMILK, ALMOND MILK, OR RICE MILK)?
10. How many 1 CUP servings of chocolate or other flavored milk (NOT SOYMILK, ALMOND MILK, OR RICE MILK), glass or with cereal or oatmeal, do you consume per day?
    a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
11. How many 1 CUP servings of chocolate or other flavored milk (NOT SOYMILK, ALMOND MILK, OR RICE MILK), glass or with cereal or oatmeal, do you consume per week?
    a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
12. How many 1 CUP servings of chocolate or other flavored milk (NOT SOYMILK, ALMOND MILK, OR RICE MILK), glass or with cereal or oatmeal, do you consume per month?
    a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
13. How often do you consume chocolate or other flavored soymilk, glass or with cereal or oatmeal?
14. How many 1 CUP servings of soymilk, glass or with cereal or oatmeal do you consume per day?
    a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
15. How many 1 CUP servings of soymilk, glass or with cereal or oatmeal do you consume per week?
    a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
16. How many 1 CUP servings of soymilk, glass or with cereal or oatmeal do you consume per month?
    a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more

**Dairy Foods**

1. How often do you consume an instant breakfast cereal drink (e.g., Carnation Instant Breakfast)?
2. How many 1 PACKET SERVINGS of an instant breakfast cereal (e.g., Carnation Instant Breakfast) do you consume per day?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
3. How many 1 PACKET SERVINGS of an instant breakfast cereal (e.g., Carnation Instant Breakfast) do you consume per week?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
4. How many 1 PACKET SERVINGS of an instant breakfast cereal (e.g., Carnation Instant Breakfast) do you consume per month?
5. How often do you consume regular, sweetened, light, low calorie, or plain yogurt (NOT frozen)?
   a. Daily
   b. Weekly
   c. Monthly
   d. Never

6. How many 1 CUP servings of regular, sweetened, light, low calorie, or plain yogurt (NOT frozen) do you consume per day?
   a. 1 b.2 c.3 d.4 e.5 f.6 g.7 h.8 i.9 j.10 or more

7. How many 1 CUP servings of regular, sweetened, light, low calorie, or plain yogurt (NOT frozen) do you consume per week?
   a. 1 b.2 c.3 d.4 e.5 f.6 g.7 h.8 i.9 j.10 or more

8. How many 1 CUP servings of regular, sweetened, light, low calorie, or plain yogurt (NOT frozen) do you consume per month?
   a. 1 b.2 c.3 d.4 e.5 f.6 g.7 h.8 i.9 j.10 or more

9. How often do you consume milkshakes?
   a. Daily
   b. Weekly
   c. Monthly
   d. Never

10. How many 1 CUP servings of a milkshake do you consume per day?
    a. 1 b.2 c.3 d.4 e.5 f.6 g.7 h.8 i.9 j.10 or more

11. How many 1 CUP servings of a milkshake do you consume per week?
    a. 1 b.2 c.3 d.4 e.5 f.6 g.7 h.8 i.9 j.10 or more

12. How many 1 CUP servings of a milkshake do you consume per month?
    a. 1 b.2 c.3 d.4 e.5 f.6 g.7 h.8 i.9 j.10 or more

13. How often do you consume frozen yogurt?
    a. Daily
    b. Weekly
    c. Monthly
    d. Never

14. How many ½ CUP servings of frozen yogurt do you consume per day?
    a. 1 b.2 c.3 d.4 e.5 f.6 g.7 h.8 i.9 j.10 or more

15. How many ½ CUP servings of frozen yogurt do you consume per week?
    a. 1 b.2 c.3 d.4 e.5 f.6 g.7 h.8 i.9 j.10 or more

16. How many ½ CUP servings of frozen yogurt do you consume per month?
    a. 1 b.2 c.3 d.4 e.5 f.6 g.7 h.8 i.9 j.10 or more

17. How often do you consume frappes?
    a. Daily
    b. Weekly
    c. Monthly
    d. Never

18. How many 1 and ½ cup servings of frappe so you consume per day?
    a. 1 b.2 c.3 d.4 e.5 f.6 g.7 h.8 i.9 j.10 or more

19. How many 1 and ½ cup servings of frappe so you consume per week?
    a. 1 b.2 c.3 d.4 e.5 f.6 g.7 h.8 i.9 j.10 or more

20. How many 1 and ½ cup servings of frappe so you consume per month?
    a. 1 b.2 c.3 d.4 e.5 f.6 g.7 h.8 i.9 j.10 or more

21. How often do you consume pudding?
    a. Daily
    b. Weekly
    c. Monthly
    d. Never
22. How many 1 PUDDING CUP servings do you consume per day?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
23. How many 1 PUDDING CUP servings do you consume per week?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
24. How many 1 PUDDING CUP servings do you consume per month?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
25. How often do you consume ice cream?
   a. Daily  
   b. Weekly  
   c. Monthly  
   d. Never
26. How many 1 CUP servings of ice cream do you consume per day?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
27. How many 1 CUP servings of ice cream do you consume per week?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
28. How many 1 CUP servings of ice cream do you consume per month?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
29. How often do you consume RICOTTA cheese?
   a. Daily  
   b. Weekly  
   c. Monthly  
   d. Never
30. How many ½ CUP servings of RICOTTA cheese do you consume per day?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
31. How many ½ CUP servings of RICOTTA cheese do you consume per week?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
32. How many ½ CUP servings of RICOTTA cheese do you consume per month?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
33. How often do you consume CHEDDAR cheese?
   a. Daily  
   b. Weekly  
   c. Monthly  
   d. Never
34. How many 1 OUNCE servings of CHEDDAR cheese do you consume per day?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
35. How many 1 OUNCE servings of CHEDDAR cheese do you consume per week?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
36. How many 1 OUNCE servings of CHEDDAR cheese do you consume per month?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
37. How often do you consume SWISS cheese?
   a. Daily  
   b. Weekly  
   c. Monthly  
   d. Never
38. How many 1 OUNCE servings of SWISS cheese do you consume per day?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
39. How many 1 OUNCE servings of SWISS cheese do you consume per week?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
40. How many 1 OUNCE servings of SWISS cheese do you consume per month?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
41. How often do you consume GOUDA/MUENSTER/PROVOLONE cheese?
   a. Daily  
   b. Weekly
c. Monthly
   d. Never
42. How many 1 OUNCE servings of GOUDA/MUENSTER/PROVOLONE cheese do you consume per day?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
43. How many 1 OUNCE servings of GOUDA/MUENSTER/PROVOLONE cheese do you consume per week?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
44. How many 1 OUNCE servings of GOUDA/MUENSTER/PROVOLONE cheese do you consume per month?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
45. How often do you consume MOZZARELLA cheese?
   a. Daily
   b. Weekly
   c. Monthly
   d. Never
46. How many 1 OUNCE servings of MOZZARELLA cheese do you consume per day?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
47. How many 1 OUNCE servings of MOZZARELLA cheese do you consume per week?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
48. How many 1 OUNCE servings of MOZZARELLA cheese do you consume per month?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
49. How often do you consume AMERICAN cheese?
   a. Daily
   b. Weekly
   c. Monthly
   d. Never
50. How many 1 OUNCE slices of AMERICAN cheese do you consume per day?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
51. How many 1 OUNCE slices of AMERICAN cheese do you consume per week?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
52. How many 1 OUNCE slices of AMERICAN cheese do you consume per month?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
53. How often do you consume string cheese?
   a. Daily
   b. Weekly
   c. Monthly
   d. Never
54. How many 1 OUNCE string cheese sticks do you consume per day?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
55. How many 1 OUNCE string cheese sticks do you consume per week?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
56. How many 1 OUNCE string cheese sticks do you consume per month?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
57. How often do you consume FETA cheese?
   a. Daily
   b. Weekly
   c. Monthly
   d. Never
58. How many 1 OUNCE servings of FETA cheese do you consume per day?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
59. How many 1 OUNCE servings of FETA cheese do you consume per week?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
60. How many 1 OUNCE servings of FETA cheese do you consume per month?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
61. How often do you consume grated PARMESAN cheese?
   a. Daily
   b. Weekly
   c. Monthly
   d. Never
62. How many 1 OUNCE servings of grated PARMESAN cheese do you consume per day?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
63. How many 1 OUNCE servings of grated PARMESAN cheese do you consume per week?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
64. How many 1 OUNCE servings of grated PARMESAN cheese do you consume per month?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
65. How often do you consume cream cheese?
   a. Daily
   b. Weekly
   c. Monthly
   d. Never
66. How many 2 TABLESPOON servings of CREAM CHEESE do you consume per day?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
67. How many 2 TABLESPOON servings of CREAM CHEESE do you consume per week?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
68. How many 2 TABLESPOON servings of CREAM CHEESE do you consume per month?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
69. How often do you consume COTTAGE cheese?
   a. Daily
   b. Weekly
   c. Monthly
   d. Never
70. How many ½ CUP servings of COTTAGE cheese do you consume per day?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
71. How many ½ CUP servings of COTTAGE cheese do you consume per week?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
72. How many ½ CUP servings of COTTAGE cheese do you consume per month?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
73. Please list any other types of cheese that you consume that are not listed____

Part IV Non-Dairy Food Choices

1. How often do you consume broccoli?
   a. Daily
   b. Weekly
   c. Monthly
   d. Never
2. How many ½ CUP servings of broccoli do you consume per day?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
3. How many ½ CUP servings of broccoli do you consume per week?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
4. How many ½ CUP servings of broccoli do you consume per month?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
5. How often do you consume canned salmon WITH bones?
   a. Daily
   b. Weekly
6. How many 3 OUNCE servings of canned salmon WITH bones do you consume per day?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
7. How many 3 OUNCE servings of canned salmon WITH bones do you consume per week?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
8. How many 3 OUNCE servings of canned salmon WITH bones do you consume per month?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
9. How often do you consume whole oranges, NOT orange juice?
   a. Daily
   b. Weekly
   c. Monthly
   d. Never
10. How many whole oranges, NOT orange juice, do you consume per day?
    a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
11. How many whole oranges, NOT orange juice, do you consume per week?
    a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
12. How many whole oranges, NOT orange juice, do you consume per month?
    a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
13. How often do you consume cooked PINTO beans?
    a. Daily
    b. Weekly
    c. Monthly
    d. Never
14. How many ½ CUP servings of PINTO beans do you consume per day?
    a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
15. How many ½ CUP servings of PINTO beans do you consume per week?
    a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
16. How many ½ CUP servings of PINTO beans do you consume per month?
    a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
17. How often do you consume canned NAVY beans?
    a. Daily
    b. Weekly
    c. Monthly
    d. Never
18. How many ½ CUP servings of canned NAVY beans do you consume per day?
    a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
19. How many ½ CUP servings of canned NAVY beans do you consume per week?
    a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
20. How many ½ CUP servings of canned NAVY beans do you consume per month?
    a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
21. How often do you consume cooked rhubarb?
    a. Daily
    b. Weekly
    c. Monthly
    d. Never
22. How many ½ CUP servings of cooked rhubarb do you consume per day?
    a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
23. How many ½ CUP servings of cooked rhubarb do you consume per week?
    a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
24. How many ½ CUP servings of cooked rhubarb do you consume per month?
    a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
25. How often do you consume spinach?
26. How many ½ CUP servings of spinach do you consume per day?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more

27. How many ½ CUP servings of spinach do you consume per week?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more

28. How many ½ CUP servings of spinach do you consume per month?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more

29. How often do you consume cooked bok choy?

30. How many 1 CUP servings of cooked bok choy do you consume per day?
    a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more

31. How many 1 CUP servings of cooked bok choy do you consume per week?
    a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more

32. How many 1 CUP servings of cooked bok choy do you consume per month?
    a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more

33. How often do you consume whole artichokes?

34. How many 1 MEDIUM artichokes do you consume per day?
    a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more

35. How many 1 MEDIUM artichokes do you consume per week?
    a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more

36. How many 1 MEDIUM artichokes do you consume per month?
    a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more

37. How often do you consume kale?

38. How many 1 CUP servings of kale do you consume per day?
    a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more

39. How many 1 CUP servings of kale do you consume per week?
    a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more

40. How many 1 CUP servings of kale do you consume per month?
    a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more

41. How often do you consume hummus?

42. How many ½ CUP servings of hummus do you consume per day?
    a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more

43. How many ½ CUP servings of hummus do you consume per week?
    a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more

44. How many ½ CUP servings of hummus do you consume per month?
45. How often do you consume figs?
   a. Daily
   b. Weekly
   c. Monthly
   d. Never

46. How many 2 MEDIUM fig servings do you consume per day?
   a. 1
   b. 2
   c. 3
   d. 4
   e. 5
   f. 6
   g. 7
   h. 8
   i. 9
   j. 10 or more

47. How many 2 MEDIUM fig servings do you consume per week?
   a. 1
   b. 2
   c. 3
   d. 4
   e. 5
   f. 6
   g. 7
   h. 8
   i. 9
   j. 10 or more

48. How many 2 MEDIUM fig servings do you consume per month?
   a. 1
   b. 2
   c. 3
   d. 4
   e. 5
   f. 6
   g. 7
   h. 8
   i. 9
   j. 10 or more

49. How often do you consume bread?
   a. Daily
   b. Weekly
   c. Monthly
   d. Never

50. How many 1 SLICE servings of bread do you consume per day?
   a. 1
   b. 2
   c. 3
   d. 4
   e. 5
   f. 6
   g. 7
   h. 8
   i. 9
   j. 10 or more

51. How many 1 SLICE servings of bread do you consume per week?
   a. 1
   b. 2
   c. 3
   d. 4
   e. 5
   f. 6
   g. 7
   h. 8
   i. 9
   j. 10 or more

52. How many 1 SLICE servings of bread do you consume per month?
   a. 1
   b. 2
   c. 3
   d. 4
   e. 5
   f. 6
   g. 7
   h. 8
   i. 9
   j. 10 or more

53. How often do you consume collards?
   a. Daily
   b. Weekly
   c. Monthly
   d. Never

54. How many ½ CUP servings of collards do you consume per day?
   a. 1
   b. 2
   c. 3
   d. 4
   e. 5
   f. 6
   g. 7
   h. 8
   i. 9
   j. 10 or more

55. How many ½ CUP servings of collards do you consume per week?
   a. 1
   b. 2
   c. 3
   d. 4
   e. 5
   f. 6
   g. 7
   h. 8
   i. 9
   j. 10 or more

56. How many ½ CUP servings of collards do you consume per month?
   a. 1
   b. 2
   c. 3
   d. 4
   e. 5
   f. 6
   g. 7
   h. 8
   i. 9
   j. 10 or more

57. How often do you consume boiled turnip greens?
   a. Daily
   b. Weekly
   c. Monthly
   d. Never

58. How many ½ CUP servings of boiled turnip greens do you consume per day?
   a. 1
   b. 2
   c. 3
   d. 4
   e. 5
   f. 6
   g. 7
   h. 8
   i. 9
   j. 10 or more

59. How many ½ CUP servings of boiled turnip greens do you consume per week?
   a. 1
   b. 2
   c. 3
   d. 4
   e. 5
   f. 6
   g. 7
   h. 8
   i. 9
   j. 10 or more

60. How many ½ CUP servings of boiled turnip greens do you consume per month?
   a. 1
   b. 2
   c. 3
   d. 4
   e. 5
   f. 6
   g. 7
   h. 8
   i. 9
   j. 10 or more

61. How often do you consume dried, whole sesame seeds?
   a. Daily
   b. Weekly
   c. Monthly
   d. Never

62. How many 1 TABLESPOONS of dried, whole sesame seeds do you consume per day?
   a. 1
   b. 2
   c. 3
   d. 4
   e. 5
   f. 6
   g. 7
   h. 8
   i. 9
   j. 10 or more

63. How many 1 TABLESPOONS of dried, whole sesame seeds do you consume per week?
64. How many 1 TABLESPOONS of dried, whole sesame seeds do you consume per month?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more

65. How often do you consume roasted sesame butter (tahini)?
   a. Daily  
   b. Weekly  
   c. Monthly  
   d. Never

66. How many 1 TABLESPOON servings of roasted sesame butter (tahini) do you consume per day?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more

67. How many 1 TABLESPOON servings of roasted sesame butter (tahini) do you consume per week?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more

68. How many 1 TABLESPOON servings of roasted sesame butter (tahini) do you consume per month?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more

69. How often do you consume rainbow trout?
   a. Daily  
   b. Weekly  
   c. Monthly  
   d. Never

70. How many 3 OUNCE servings of rainbow trout do you consume per day?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more

71. How many 3 OUNCE servings of rainbow trout do you consume per week?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more

72. How many 3 OUNCE servings of rainbow trout do you consume per month?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more

73. How often do you consume dried almonds?
   a. Daily  
   b. Weekly  
   c. Monthly  
   d. Never

74. How many ½ OUNCE servings (12 NUTS) of dried almonds do you consume per day?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more

75. How many ½ OUNCE servings (12 NUTS) of dried almonds do you consume per week?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more

76. How many ½ OUNCE servings (12 NUTS) of dried almonds do you consume per month?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more

77. How often do you consume cold breakfast cereal?
   a. Daily  
   b. Weekly  
   c. Monthly  
   d. Never

78. How many 1 CUP servings of cold breakfast cereal do you consume per day?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more

79. How many 1 CUP servings of cold breakfast cereal do you consume per week?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more

80. How many 1 CUP servings of cold breakfast cereal do you consume per month?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more

81. Please write the name of the cereal that you consume MOST OFTEN

82. How often do you consume cereal bars (e.g., granola bars, cereal bars, meal replacement bars, etc.)?
   a. Daily
83. How many cereal bars do you consume per day?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
84. How many cereal bars do you consume per week?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
85. How many cereal bars do you consume per month?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
86. Please write the name of the cereal bar that you consume MOST OFTEN
87. How often do you consume ORANGE JUICE (NOT whole oranges)?
88. How many ½ CUP servings of ORANGE JUICE (NOT whole oranges) do you consume per day?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
89. How many ½ CUP servings of ORANGE JUICE (NOT whole oranges) do you consume per week?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
90. How many ½ CUP servings of ORANGE JUICE (NOT whole oranges) do you consume per month?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
91. How often do you consume grapefruit juice?
92. How many ½ CUP servings of grapefruit juice do you consume per day?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
93. How many ½ CUP servings of grapefruit juice do you consume per week?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
94. How many ½ CUP servings of grapefruit juice do you consume per month?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
95. How often do you consume firm tofu, set in calcium?
96. How many ½ CUP servings of firm tofu, set in calcium do you consume per day?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
97. How many ½ CUP servings of firm tofu, set in calcium do you consume per week?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more
98. How many ½ CUP servings of firm tofu, set in calcium do you consume per month?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more

Part VI: Supplements

1. Do you take any supplements?
   a. Yes  b. No  c. Unsure
2. Do you take a calcium supplement?
1. Are you a man or woman?
   a. Male
   b. Female
   c. Unsure

2. Are you taking any supplement that contains omega-3 fats?
   a. Yes
   b. No
   c. Unsure

3. Do you take a multivitamin?
   a. Yes
   b. No
   c. Unsure

4. What kind of multivitamin do you consume?
   a. Centrum Under 50
   b. Centrum Women’s
   c. Centrum Men’s
   d. Women’s One-a-Day
   e. Flintstone Gummies
   f. Kirkland Multivitamin
   g. Unsure
   h. Other (please specify): ___

5. What kind of calcium do you take?
   a. Citracel
   b. Citracel with vitamin D
   c. Viactiv soft chews calcium with vitamin D
   d. Viactiv soft chews multivitamin
   e. Solgar
   f. Solgar with vitamin D
   g. Caltrate
   h. Tums
   i. Unsure
   j. Other (please specify): ___

6. How many milligrams of calcium does your supplement contain? If you don’t know write “unsure”.

7. How often do you take your calcium supplement?
   a. Daily
   b. Weekly
   c. Monthly
   d. Never

8. How many calcium supplements (number of pills, chews, etc.) do you consume per day?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more

9. How many calcium supplements (number of pills, chews, etc.) do you consume per week?
   a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more

10. How many calcium supplements (number of pills, chews, etc.) do you consume per month?
    a. 1  b. 2  c. 3  d. 4  e. 5  f. 6  g. 7  h. 8  i. 9  j. 10 or more

Thank you for taking this survey. If you wish to be entered into the drawing for a $25 gift card for Starbucks, please enter your email address below: _______________
APPENDIX C

CALCIUM CONTENT OF FOOD PRODUCTS UTILIZED IN QUESTIONNAIRE
# Appendix C

## Calcium Content of Food Products Utilized in Questionnaire

Complete list of foods utilized in the food-questionnaire survey with corresponding calcium per serving in milligrams (mg).

<table>
<thead>
<tr>
<th>Food item</th>
<th>Serving size</th>
<th>Calcium (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Almonds, dried</td>
<td>1/2 oz. (12)</td>
<td>37</td>
</tr>
<tr>
<td>American cheese</td>
<td>1 oz.</td>
<td>141</td>
</tr>
<tr>
<td>Artichoke</td>
<td>1 medium</td>
<td>54</td>
</tr>
<tr>
<td>Bok choy</td>
<td>1 cup</td>
<td>40</td>
</tr>
<tr>
<td>Bread</td>
<td>1 slice</td>
<td>32</td>
</tr>
<tr>
<td>Broccoli, cooked</td>
<td>1/2 cup</td>
<td>35</td>
</tr>
<tr>
<td>Cheddar cheese</td>
<td>1 oz.</td>
<td>204</td>
</tr>
<tr>
<td>Chocolate milk</td>
<td>8 oz.</td>
<td>280</td>
</tr>
<tr>
<td>Collards, boiled</td>
<td>1/2 cup</td>
<td>110</td>
</tr>
<tr>
<td>Cottage cheese</td>
<td>1/2 cup</td>
<td>68</td>
</tr>
<tr>
<td>Cream cheese</td>
<td>1 oz. (2 Tbsp.)</td>
<td>23</td>
</tr>
<tr>
<td>Feta cheese</td>
<td>1 oz.</td>
<td>140</td>
</tr>
<tr>
<td>Figs, fresh</td>
<td>2 medium</td>
<td>35</td>
</tr>
<tr>
<td>Frappe</td>
<td>1 1/2 cup</td>
<td>200</td>
</tr>
<tr>
<td>Frozen yogurt</td>
<td>4 oz.</td>
<td>72</td>
</tr>
<tr>
<td>Gouda/muenster/provolone cheese</td>
<td>1 oz.</td>
<td>198</td>
</tr>
<tr>
<td>Grapefruit juice</td>
<td>½ cup</td>
<td>20</td>
</tr>
<tr>
<td>Hummus</td>
<td>1/2 cup</td>
<td>24</td>
</tr>
<tr>
<td>Ice cream</td>
<td>1 cup</td>
<td>130</td>
</tr>
<tr>
<td>Instant breakfast drink (i.e., Carnation)</td>
<td>1 packet</td>
<td>250</td>
</tr>
<tr>
<td>Kale</td>
<td>1 cup</td>
<td>50</td>
</tr>
<tr>
<td>Milk</td>
<td>8 oz.</td>
<td>300</td>
</tr>
<tr>
<td>Milkshakes</td>
<td>1 cup</td>
<td>300</td>
</tr>
<tr>
<td>Mozzarella cheese</td>
<td>1 oz.</td>
<td>183</td>
</tr>
<tr>
<td>Navy beans, canned</td>
<td>1/2 cup</td>
<td>61</td>
</tr>
<tr>
<td>Orange</td>
<td>1 fresh</td>
<td>52</td>
</tr>
<tr>
<td>Orange juice, calcium fortified</td>
<td>1/2 cup</td>
<td>100</td>
</tr>
<tr>
<td>Parmesan cheese, grated</td>
<td>2 Tbsp.</td>
<td>138</td>
</tr>
<tr>
<td>Pinto beans, canned</td>
<td>1/2 cup</td>
<td>43</td>
</tr>
<tr>
<td>Pudding</td>
<td>1 pudding cup</td>
<td>135</td>
</tr>
<tr>
<td>Rhubarb, cooked</td>
<td>1/2 cup</td>
<td>132</td>
</tr>
<tr>
<td>Ricotta cheese, part skim</td>
<td>1/2 cup</td>
<td>257</td>
</tr>
<tr>
<td>Salmon, canned with bones</td>
<td>3 oz.</td>
<td>200</td>
</tr>
</tbody>
</table>
List of major calcium-fortified cereal bars with their corresponding calcium content, in milligrams (mg), per bar.

<table>
<thead>
<tr>
<th>Fortified Cereal Bar</th>
<th>Serving Size</th>
<th>Ca2+ (mg)</th>
<th>Brand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cinnamon Toast Crunch Milk n’ Cereal</td>
<td>1 bar</td>
<td>250</td>
<td>GM</td>
</tr>
<tr>
<td>Honey Nut Cheerios Milk n’ Cereal</td>
<td>1 bar</td>
<td>250</td>
<td>GM</td>
</tr>
<tr>
<td>Fiber Plus, Nutty Delights, Honey Roasted Almond</td>
<td>1 bar</td>
<td>100</td>
<td>Kellogg’s</td>
</tr>
<tr>
<td>Fiber Plus, Protein Bar, Mixed Nut</td>
<td>1 bar</td>
<td>150</td>
<td>Kellogg’s</td>
</tr>
<tr>
<td>Fiber Plus, Protein Bar, Peanut</td>
<td>1 bar</td>
<td>150</td>
<td>Kellogg’s</td>
</tr>
<tr>
<td>Fiber Plus, Chocolate Chip</td>
<td>1 bar</td>
<td>100</td>
<td>Kellogg’s</td>
</tr>
<tr>
<td>Fiber Plus, Chocolate Peanut Butter</td>
<td>1 bar</td>
<td>100</td>
<td>Kellogg’s</td>
</tr>
<tr>
<td>Fiber Plus, Dark Chocolate Almond</td>
<td>1 bar</td>
<td>100</td>
<td>Kellogg’s</td>
</tr>
<tr>
<td>Special K Protein Meal Bar, Caramel</td>
<td>1 bar</td>
<td>200</td>
<td>Kellogg’s</td>
</tr>
<tr>
<td>Special K Protein Meal Bar, Chocolate Peanut Butter</td>
<td>1 bar</td>
<td>200</td>
<td>Kellogg’s</td>
</tr>
<tr>
<td>Special K Protein Meal Bar, Cranberry Walnut</td>
<td>1 bar</td>
<td>200</td>
<td>Kellogg’s</td>
</tr>
<tr>
<td>Special K Protein Meal Bar, Double Chocolate</td>
<td>1 bar</td>
<td>200</td>
<td>Kellogg’s</td>
</tr>
<tr>
<td>Special K Protein Meal Bar, Honey Almond</td>
<td>1 bar</td>
<td>200</td>
<td>Kellogg’s</td>
</tr>
<tr>
<td>Special K Protein Meal Bar, Strawberry</td>
<td>1 bar</td>
<td>250</td>
<td>Kellogg’s</td>
</tr>
<tr>
<td>Chewy granola bars, chocolate chip</td>
<td>1 bar</td>
<td>100</td>
<td>Quaker</td>
</tr>
<tr>
<td>Chewy granola bars, cookies and cream</td>
<td>1 bar</td>
<td>100</td>
<td>Quaker</td>
</tr>
<tr>
<td>Chewy granola bars, honey graham</td>
<td>1 bar</td>
<td>100</td>
<td>Quaker</td>
</tr>
<tr>
<td>Chewy granola bars, peanut butter chocolate chip</td>
<td>1 bar</td>
<td>100</td>
<td>Quaker</td>
</tr>
<tr>
<td>Chewy granola bars, chocolate chunk</td>
<td>1 bar</td>
<td>80</td>
<td>Quaker</td>
</tr>
<tr>
<td>Chewy granola bars, dark chocolate cherry</td>
<td>1 bar</td>
<td>80</td>
<td>Quaker</td>
</tr>
<tr>
<td>Chewy granola bars, oatmeal raisin</td>
<td>1 bar</td>
<td>80</td>
<td>Quaker</td>
</tr>
<tr>
<td>Chewy granola bars, peanut butter</td>
<td>1 bar</td>
<td>80</td>
<td>Quaker</td>
</tr>
<tr>
<td>Chewy granola bars, s’mores</td>
<td>1 bar</td>
<td>80</td>
<td>Quaker</td>
</tr>
<tr>
<td>Quaker chewy dips granola bar, cookies and cream</td>
<td>1 bar</td>
<td>80</td>
<td>Quaker</td>
</tr>
<tr>
<td>Chewy granola bars, chocolate chip</td>
<td>1 bar</td>
<td>80</td>
<td>Quaker</td>
</tr>
<tr>
<td>Oatmeal to go, apples with cinnamon</td>
<td>1 bar</td>
<td>200</td>
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<tr>
<td>Oatmeal to go, banana bread</td>
<td>1 bar</td>
<td>200</td>
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</tr>
<tr>
<td>Oatmeal to go, brown sugar and cinnamon</td>
<td>1 bar</td>
<td>200</td>
<td>Quaker</td>
</tr>
<tr>
<td>Oatmeal to go, high fiber maple brown sugar</td>
<td>1 bar</td>
<td>150</td>
<td>Quaker</td>
</tr>
<tr>
<td>Oatmeal to go, oatmeal raisin</td>
<td>1 bar</td>
<td>200</td>
<td>Quaker</td>
</tr>
<tr>
<td>Yogurt granola bars, blueberry</td>
<td>1 bar</td>
<td>100</td>
<td>Quaker</td>
</tr>
<tr>
<td>Yogurt granola bars, strawberry</td>
<td>1 bar</td>
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</tr>
<tr>
<td>Yogurt granola bars, vanilla</td>
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<td>Special K Protein Meal Bar, Honey Almond</td>
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</tr>
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<td>Special K Protein Meal Bar, Strawberry</td>
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<td>Chewy granola bars, cookies and cream</td>
<td>1 bar</td>
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<td>Quaker</td>
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<tr>
<td>Chewy granola bars, honey graham</td>
<td>1 bar</td>
<td>100</td>
<td>Quaker</td>
</tr>
<tr>
<td>Chewy granola bars, peanut butter chocolate chip</td>
<td>1 bar</td>
<td>100</td>
<td>Quaker</td>
</tr>
<tr>
<td>Chewy granola bars, chocolate chunk</td>
<td>1 bar</td>
<td>80</td>
<td>Quaker</td>
</tr>
<tr>
<td>Chewy granola bars, dark chocolate cherry</td>
<td>1 bar</td>
<td>80</td>
<td>Quaker</td>
</tr>
<tr>
<td>Chewy granola bars, 90 calorie, oatmeal raisin</td>
<td>1 bar</td>
<td>80</td>
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<tr>
<td>Chewy granola bars, 90 calorie, peanut butter</td>
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<td>100</td>
<td>Quaker</td>
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<tr>
<td>Chewy granola bars, 90 calorie, s’mores</td>
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<td>80</td>
<td>Quaker</td>
</tr>
<tr>
<td>Quaker chewy dips granola bar, cookies and cream</td>
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<td>80</td>
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</tr>
<tr>
<td>Item</td>
<td>Quantity</td>
<td>Calories</td>
<td>Brand</td>
</tr>
<tr>
<td>-----------------------------------------------------</td>
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<tr>
<td>Chewy granola bars, chocolate chip</td>
<td>1 bar</td>
<td>80</td>
<td>Quaker</td>
</tr>
<tr>
<td>Chewy granola bars, peanut butter chocolate chip</td>
<td>1 bar</td>
<td>100</td>
<td>Quaker</td>
</tr>
<tr>
<td>Oatmeal to go, apples with cinnamon</td>
<td>1 bar</td>
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<td>Quaker</td>
</tr>
<tr>
<td>Oatmeal to go, banana bread</td>
<td>1 bar</td>
<td>200</td>
<td>Quaker</td>
</tr>
<tr>
<td>Oatmeal to go, brown sugar and cinnamon</td>
<td>1 bar</td>
<td>200</td>
<td>Quaker</td>
</tr>
<tr>
<td>Oatmeal to go, high fiber maple brown sugar</td>
<td>1 bar</td>
<td>150</td>
<td>Quaker</td>
</tr>
<tr>
<td>Oatmeal to go, oatmeal raisin</td>
<td>1 bar</td>
<td>200</td>
<td>Quaker</td>
</tr>
<tr>
<td>Yogurt granola bars, blueberry</td>
<td>1 bar</td>
<td>100</td>
<td>Quaker</td>
</tr>
<tr>
<td>Yogurt granola bars, strawberry</td>
<td>1 bar</td>
<td>100</td>
<td>Quaker</td>
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</table>
List of calcium-fortified cereals and amount of calcium in milligrams (mg) per serving. Note that this is the calcium content WITHOUT milk.

<table>
<thead>
<tr>
<th>Fortified Cereal</th>
<th>Serving</th>
<th>Calcium (mg)</th>
<th>Brand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole Grain Total</td>
<td>3/4 cup</td>
<td>1000</td>
<td>GM</td>
</tr>
<tr>
<td>Total Raisin Bran</td>
<td>1 cup</td>
<td>1000</td>
<td>GM</td>
</tr>
<tr>
<td>Total Cranberry Crunch</td>
<td>1 1/4 cup</td>
<td>1000</td>
<td>GM</td>
</tr>
<tr>
<td>Cheerios</td>
<td>1 cup</td>
<td>100</td>
<td>GM</td>
</tr>
<tr>
<td>Cinnamon Toast Crunch</td>
<td>3/4 cup</td>
<td>100</td>
<td>GM</td>
</tr>
<tr>
<td>Cheerios, apple cinnamon</td>
<td>3/4 cup</td>
<td>100</td>
<td>GM</td>
</tr>
<tr>
<td>Cheerios, banana nut</td>
<td>3/4 cup</td>
<td>100</td>
<td>GM</td>
</tr>
<tr>
<td>Berry Berry Kix</td>
<td>1 1/4 cup</td>
<td>150</td>
<td>GM</td>
</tr>
<tr>
<td>Boo Berry</td>
<td>1 cup</td>
<td>100</td>
<td>GM</td>
</tr>
<tr>
<td>Chex, apple cinnamon</td>
<td>3/4 cup</td>
<td>100</td>
<td>GM</td>
</tr>
<tr>
<td>Chex, chocolate</td>
<td>3/4 cup</td>
<td>100</td>
<td>GM</td>
</tr>
<tr>
<td>Chex, cinnamon</td>
<td>3/4 cup</td>
<td>100</td>
<td>GM</td>
</tr>
<tr>
<td>Chex, corn</td>
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</tr>
<tr>
<td>Chex, honey nut</td>
<td>3/4 cup</td>
<td>100</td>
<td>GM</td>
</tr>
<tr>
<td>Chex, multi bran</td>
<td>3/4 cup</td>
<td>100</td>
<td>GM</td>
</tr>
<tr>
<td>Chex, rice</td>
<td>1 cup</td>
<td>100</td>
<td>GM</td>
</tr>
<tr>
<td>Chex, wheat</td>
<td>3/4 cup</td>
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<td>GM</td>
</tr>
<tr>
<td>Cheerios, chocolate</td>
<td>3/4 cup</td>
<td>100</td>
<td>GM</td>
</tr>
<tr>
<td>Cheerios, cinnamon burst</td>
<td>1 cup</td>
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</tr>
<tr>
<td>Cocoa Puffs</td>
<td>3/4 cup</td>
<td>100</td>
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</tr>
<tr>
<td>Cookie Crisp</td>
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</tr>
<tr>
<td>Fiber one</td>
<td>1/2 cup</td>
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</tr>
<tr>
<td>Fiber one, 80 calories</td>
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<td>400</td>
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<tr>
<td>Fiber one, caramel delight</td>
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</tr>
<tr>
<td>Fiber one, honey clusters</td>
<td>1 cup</td>
<td>100</td>
<td>GM</td>
</tr>
<tr>
<td>Fiber one, nutty clusters and almonds</td>
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<td>100</td>
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</tr>
<tr>
<td>Fiber one, raisin bran clusters</td>
<td>1 cup</td>
<td>100</td>
<td>GM</td>
</tr>
<tr>
<td>Golden Grahams</td>
<td>3/4 cup</td>
<td>100</td>
<td>GM</td>
</tr>
<tr>
<td>Cheerios, honey nut</td>
<td>3/4 cup</td>
<td>100</td>
<td>GM</td>
</tr>
<tr>
<td>Kix</td>
<td>1 1/4 cup</td>
<td>150</td>
<td>GM</td>
</tr>
<tr>
<td>Lucky Charms</td>
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<td>100</td>
<td>GM</td>
</tr>
<tr>
<td>Cheerios, multi-grain</td>
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<td>GM</td>
</tr>
<tr>
<td>Reese’s Puffs</td>
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<td>100</td>
<td>GM</td>
</tr>
<tr>
<td>Trix</td>
<td>1 cup</td>
<td>100</td>
<td>GM</td>
</tr>
<tr>
<td>All Bran, original</td>
<td>1/2 cup</td>
<td>100</td>
<td>Kellogg’s</td>
</tr>
<tr>
<td>Life Cereal, cinnamon</td>
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<td>100</td>
<td>Quaker Oats</td>
</tr>
<tr>
<td>Life Cereal, maple and brown sugar</td>
<td>3/4 cup</td>
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<td>Quaker Oats</td>
</tr>
<tr>
<td>Life Cereal</td>
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<td>Quaker Oats</td>
</tr>
<tr>
<td>Life Crunchtime, apple cinnamon</td>
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<td>Quaker Oats</td>
</tr>
<tr>
<td>Life Crunchtime, strawberry</td>
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<tr>
<td>Oatmeal Squares, brown sugar</td>
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<tr>
<td>Oatmeal Squares, cinnamon</td>
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<td>Quaker Oats</td>
</tr>
<tr>
<td>Oatmeal Squares, golden maple</td>
<td>1 cup</td>
<td>100</td>
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</tr>
<tr>
<td>Oatmeal Squares, honey nut</td>
<td>1 cup</td>
<td>80</td>
<td>Quaker Oats</td>
</tr>
</tbody>
</table>
REFERENCES


