Chapter I

Introduction

The human bone has made mainly of collagen; this is living and growing tissue also. Collagen is a kind of protein that provides a soft frame, and calcium phosphate is a mineral that adds strength and hardens the structure. The mixture of collagen and calcium makes bone powerful and flexible enough to endure stress. Further than 99 percent of the body's calcium is included in the teeth and bones. The left over 1 percent is located in the blood. (Cowin, 2001; Standring, 2008)

Structure of the Bone

It is essential for bones to be strong to maintain the body weight and in some cases supply protection for instance the skull and ribs. However, the bones must also be light adequate to make movement possible. A long bone consists of four sections: Diaphysis; Epiphysis; Metaphysis; Epiphyseal Plates. A layer of hyaline cartilage has covered the ends of bones in joints. This is a hard but elastic form of cartilage has no neural or vascular supply and only creates shock absorption to the joint. (Cowin, 2001; Standring, 2008)

The shaft of long bone is hollow and recognized as Medullary Cavity. This part has red and yellow bone marrow. Yellow bone marrow is mostly a fatty tissue, and the red bone marrow role is production of blood cells and there is in higher amount in the flat and irregular bones (Cowin, 2001; Standring, 2008).
Types of Bones in the Human Body

Bones have classified to five types according to shapes. These are Long Bones, Short Bones, Flat Bones, Irregular Bones and Sesamoid Bones.

Bone Development and Structure

For the reason that bone is made up of minerals and is solid, lots of people suppose it is not living matter. But bones have both living tissue and non-living material. The "alive bone" has blood vessels, nerves, collagen, and living cells consisting: Osteoblasts (help form bone) and Osteoclasts (help eat away aged bone).

The nonliving bone is very important and their materials are the minerals and salts. In addition the metabolically active cellular part of bone tissue, bone is also made up of a matrix of different materials, including primarily collagen fibers and crystalline salts. The crystalline salts accumulated in the matrix of bone has made mainly of calcium and phosphate, which are combined to form hydroxyapatite crystals.

In the fetus, a large amount of the skeleton is made up of cartilage, a flexible and hard connective tissue without minerals or salts. When the fetus grows, osteoblasts and osteoclasts gradually replace cartilage cells and ossification starts (Cowin, 2001; Standring, 2008).

Ossification

It is the creation of bone via the activity of osteoblasts, osteoclasts and the addition of minerals and salts. Calcium compounds should be available for
ossification to happen. Osteoblasts do not build these minerals, but be required to take them from the blood for deposit in the bone.

In the long bones, growing and elongation (lengthening) keep on from birth throughout adolescence. Elongation is attained by the action of two cartilage plates, called epiphyseal plates, located between the body (the diaphysis) and the heads (epiphyses) of the bones and the length of the diaphysis increases at both ends. Ossification in humans completed about age 25. During this elongating time, the pressures of physical activity results in the strengthening of bone tissue.

Naturally, in fact, excluding in growing bones, the amounts of bone deposition and absorption are the same therefore the entire mass of bone keeps constant. (Cowin, 2001; Standring, 2008)

**Bone formation**

Osteoblasts perform key roles in bone resorption. Receptors for parathyroid hormone (PTH), calcitriol (vitamin D), prostaglandins, and interleukins (compounds that enhance bone resorption) have been recognized on the surface of osteoblasts. (Martin & Ng, 1994)

**Bone resorption**

Osteoclasts are cells responsible for resorption of bone. Osteoclasts are big multinucleated cells that are found separately or in little groups at the bone surface and have ruffled borders for permits secretion of protons that are necessary to reduce the microenvironmental pH at the resorptive place, dissolve hydroxyapatite, and expose the protein matrix. (Mundy, 1996)
The Multiple Functions of Bone:

1: Mobility, Structure and Protection: The 206 bones along with tendons, ligaments, cartilage and muscles allow the body moving as well as giving strength and form. Also, bones function to protect delicate body parts as the brain, liver and heart from injury ("Functions of Bone", n.d.).

2: Blood Cell Creation: The bone core produces more than two million red blood cells that carry oxygen and nutrients throughout the body and take away waste. It also builds white blood cells, a vital part of body’s immune structure, and platelets that are required in natural blood clotting flow ("Functions of Bone", n.d.).

3: Mineral “Conductor” and PH Balancer: Bones do not use minerals for themselves but they can also store minerals required for the function of the other parts of body. Body requires minerals for to continue heart beating, brain thinking, and nervous system reacts. Furthermore, bones are responsible of monitoring the overall environment of the body well-known as the pH balance. When that environment becomes excessively acidic, a destructive condition that assaults tissues, the bones send out minerals to alkalinize the body and bring it back to steadiness ("Functions of Bone", n.d.).

4: Insulin sensitivity, Weight Control: Bones make a hormone-signaling protein called osteocalcin which stimulates pancreatic insulin secretion and improves insulin sensitivity in the whole body, by this means helping to adjust blood sugar levels, an important reason in the control of diabetes. Osteocalcin also decreases fat deposition and is connected to another hormone called leptin, the “hunger hormone,” which has a key function in regulating desire for food, metabolism, and weight management ("Functions of Bone", n.d.).
5: Cardiovascular Health: The relation between weak bone health and cardiovascular health is becoming increasingly clear. As calcium goes away the bones in the process of osteoporosis, it can build up as an alternative in the bloodstream, thus increasing the probability of risky calcified plaque deposits (atherosclerosis) that can rupture or cause obstructions, possibly causing heart attacks and stroke. But other assured-research illustrates that taking calcium in whole food form with its necessary co-factors is what body needs to build new bone, stop this process of bone breakdown/calcification, and is not harmful for body (which is why created a safe bone health supplement with plant-based calcium) ("Functions of Bone", n.d.).

In conclusion, Bone Health=Total Body Health

So, although larger parts of people think of skeleton as merely structural foundation, the bones also function as the deeper, broader groundwork for the health of whole bodies. The health of body is riding on the health of bones ("Functions of Bone", n.d.).

Nutrition and Bone:

Variations in dietary intakes of nutrients, specifically calcium (minerals) and vitamin D, impact the integrity of bone through alterations in nutrient homeostasis in the body. Bone is a storage section for several minerals within the body (Broadus, 1996) and dietary constituents are essential for synthesis and function of enzymes (Czajka-Narins, 1992), hormones, (Seelig, 1993; Zofkova, & Kancheva, 1995), and bone cells. (Czajka-Narins, 1992)

Calcium: This is the most important mineral in bone, and crystals of calcium compounds provide bone its hardness and strength (Straub, 2007). Calcium
supplementation also suppresses bone resorption, further fighting osteoporotic changes (Ortolani, Scotti & Cherubini, 2003).

Because calcium is 40% of the mineral found in bone, dietary intake of calcium has a high association with BMD. Calcium is absorbed both actively and passively from the small intestine (Bronner & Pansu, 1999). Although an abundance of research has concentrated on the relationship between calcium and BMD, dietary factors important to bone metabolism are not restricted to calcium. Several other nutrients influence bone directly or through effects on calcium economy (New, 2000; Rubin, 1999).

**Phosphorus:** This is needed for sustaining bone integrity. Phosphorus is an essential part of bone and it can decrease urinary calcium excretion, a ratio of calcium to phosphorus consumption more than 1:1 may be harmful to bone. Excessive dietary phosphorus intakes may lead to bone loss by lowering the ionized serum calcium level (Beiseigel, 2000).

**Magnesium:** This is necessary for normal bone metabolism by keeping sufficient function of the calcium adjusting hormones PTH, vitamin D and calcitonin (Seelig, 1993; Zofkova & Kancheva, 1995).

**Zinc:** This is an important component of bone that helps in bone formation. Zinc is predominantly useful to bone when dietary calcium intake is enough (Beiseigel, 2000).

**Fat, protein, sodium:** Dietary fat may bind calcium in the digestive tube (small intestine) and avoid absorption (Bronner, & Pansu, 1999). Both protein and sodium have been revealed to stimulate renal excretion of calcium (Packard & Heaney, 1997).
There is a converse correlation between high dietary intakes of fat, protein and sodium and BMD ("Food and Nutrition Board", 1999).

**Fiber**: An opposite relationship between increased fiber intake and BMD exists with information suggesting that dietary fiber prevents mineral absorption (Davidson, Mackenzie, Kastenmayer, Rose & Goden, 1996). But Fruits and vegetables are good sources of zinc, potassium, magnesium, and vitamin C and these are useful for bone (New, Bolton-Smith, Grubb, & Reid, 1997).

**Omega-3 Fatty Acids (Fish and Flax Oils)**: The omega-3 fatty acids found in fish oil (EPA and DHA) and flax oil (ALA) have influential anti-inflammatory and antioxidant impacts (Trebble et al. 2004; Fernandes, Bhattacharya, Rahman, Zaman, & Banu, 2008; Maggio et al. 2009). That makes them perfect candidates for inclusion in an anti-osteoporosis regimen, given the role of inflammation in osteoporosis (Trebble et al. 2004). EPA and DHA also decrease activity of bone-resorbing cells, enhance that of bone-forming cells, and develop calcium balance (Maggio et al. 2009).

**Vitamin D**: It is required for adequate absorption of dietary calcium in the small intestine. The deficiency (or insufficiency) of Vitamin D, besides other health troubles, can cause the body to release large levels of parathyroid hormone (secondary hyperparathyroidism) and finally can lead to bone weakening (Peacock, 2010).

Vitamin D lacks also causes muscle weakness and neurological shortages, increasing the risk of falling, which of course makes fractures still more likely (Bischoff-Ferrari et al. 2009; Pfeifer et al. 2009; Janssen, Samson & Verhaar, 2010).

**Vitamin K**: Scientists have realized that vitamin K is a vital co-factor for creation of the major bone protein, osteocalcin (Bügel, 2008; Iwamoto, Takeda, &
Sato, 2006). Vitamin K-dependent enzymes make changes in osteocalcin that permit it to tightly connect to the calcium compounds that give bone its unbelievable strength (Bügel, 2008, Wada, Fukawa, & Kamiya, 2007; Rezaieyazdi, Falsoleiman, Khajehdaluee, Saghafi, & Mokhtari-Amirmajdi, 2009).

**Antioxidant Vitamins** – The vitamins C and E are antioxidant and they play significant roles in making of proteins, development of bone-forming cells, and bone mineralization (Zinnuroglu, Dincel, Kosova, Sepici, & Karatas, 2012; Hall & Greendale, 1998). Vitamin C also suppresses activity of bone-resorbing cells while promoting maturation of bone-forming cells (Gabbay et al. 2010). Vitamin E improves bone structure, contributing to stronger bone (Shuid, Mehat, Mohamed, Muhammad & Soelaiman, 2010).

**Table 1.1: Calcium and Vitamin D Requirements**

<table>
<thead>
<tr>
<th>Age</th>
<th>Calcium (mg/day)</th>
<th>Vitamin D (IU/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infants 0-6 months</td>
<td>200 mg</td>
<td>400 IU (10 mcg)</td>
</tr>
<tr>
<td>Infants 7-12 months</td>
<td>260 mg</td>
<td>400 IU (10 mcg)</td>
</tr>
<tr>
<td>Children 1-3 years</td>
<td>700 mg</td>
<td>600 IU (15 mcg)</td>
</tr>
<tr>
<td>Children 4-8 years</td>
<td>1000 mg</td>
<td>600 IU (15 mcg)</td>
</tr>
<tr>
<td>Children 9-18 years</td>
<td>1300 mg</td>
<td>600 IU (15 mcg)</td>
</tr>
<tr>
<td>Adults 19-50 years</td>
<td>1000 mg</td>
<td>600 IU (15 mcg)</td>
</tr>
<tr>
<td>Adults 51-70 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>1000 mg</td>
<td>600 IU (15 mcg)</td>
</tr>
<tr>
<td>Women</td>
<td>1200 mg</td>
<td></td>
</tr>
<tr>
<td>Adults &gt; 70 years</td>
<td>1200 mg</td>
<td>800 IU (20 mcg)</td>
</tr>
<tr>
<td>Pregnancy &amp; Lactation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14-18 years</td>
<td>1300 mg</td>
<td>600 IU (15 mcg)</td>
</tr>
<tr>
<td>19-50 years</td>
<td>1000 mg</td>
<td></td>
</tr>
</tbody>
</table>

Source: Food and Nutrition Board, Institute of Medicine, National Academy of Sciences (2010)
Hormones and Bone:

Parathyroid

The levels of calcium increase in the blood through multiple pathways, when parathyroid hormone releases. While it increases the release of calcium from the bone, it increases the absorption of calcium from intestine and makes kidneys excrete less calcium. Parathyroid produces when the levels of calcium in the blood become low (Peacock, 2010).

Calcitonin

The effect of calcitonin opposes that of parathyroid hormone. It declines the levels of calcium in the blood by increasing the deposition of calcium in the bones (Peacock, 2010).

![Diagram of parathyroid and thyroid glands function](image)

**Figure 1.1: The parathyroid and thyroid glands function**

Disease and Bone

The most common bone disease is osteoporosis. This is characterized by low bone mass and weakening of bone structure. Other bone diseases are Paget’s disease and osteogenesis imperfecta. Paget’s disease causes skeletal deformities and fractures.
in older men and women. Osteogenesis imperfecta is an inherited disorder that causes fragile bones and frequent bone fractures in children (Smith, 2004).

**Osteoporosis**

It is a disease in which the bones become weak and are more probable to break. People with osteoporosis most frequently break bones in the hip, spine and wrist ("The National Institutes of Health", 2011).

Osteoporosis is a progressive bone illness that is described by reduce in bone mass and density and that leads to an increased risk of breaking (Alldredge, Koda-Kimble, Young, Kradjan & Guglielmo, 2009).

![Figure 1.2: Normal Bone (Left) and Osteoporotic Bone (Right)](image)

**Risk Factors for Osteoporosis**

The risk factors for osteoporosis, like those for all chronic, multi-factorial conditions, are many, and they interact with one another.

- **Gender**: The women get osteoporosis more often than men ("The National Institutes of Health", 2011).
Introduction

- **Age**: The older persons are at greater risk of osteoporosis (Mundy, 2007; Mazière et al. 2010; Seymour, Ford, Cullinan, Leishman & Yamazaki, 2007; Ruiz-Ramos, Vargas, Van der Goes, Cervantes-Sandoval & Mendoza-Nunez, 2010).

- **Body size**: Small, thin women are at greater risk of osteoporosis ("The National Institutes of Health", 2011).

- **Ethnicity**: White and Asian women have a high risk and Black and Hispanic women are a lower risk (Dhanwal, Dennison, Harvey & Cooper, 2011; Golden, Robinson, Saldanha, Anton & Ladenson, 2009).

- **Family history**: Osteoporosis tends to run in families. If a family member has osteoporosis or breaks a bone, there is a greater chance that other family member will too ("The National Institutes of Health", 2011). So a family history of hip fracture brings a twofold increased danger of fracture between descendants (Ferrari, 2008).

- **Sex hormones**: Low estrogen levels by reason of missing menstrual periods or to menopause are able to cause osteoporosis in females. Low testosterone levels can bring on osteoporosis in males ("The National Institutes of Health", 2011).

- **Anorexia nervosa**: This is an eating disorder and it can cause to osteoporosis ("The National Institutes of Health", 2011).

- **Calcium and vitamin D intake**: A diet low in calcium and vitamin D makes body more susceptible to bone loss ("The National Institutes of Health", 2011).

- **Activity level**: Lack of physical activity or long-term bed rest can cause fragile bones ("The National Institutes of Health", 2011).
• **Smoking**: Cigarettes and tobacco are bad for bones, heart and lungs, too ("The National Institutes of Health", 2011).

• **Drinking alcohol**: Drinking too much alcohol is able to cause bone loss and broken bones ("The National Institutes of Health", 2011).

• **Vertigo**: Several new studies have shown a relationship between “benign positional vertigo” (BPV) and lower BMD (Vibert, Kompis & Häusler, 2003; Vibert et al. 2008; Jeong et al. 2009).

• **Slim stature (underweight)**: People with less than 19 BMI or small body structures tend to have a advanced risk because they may have less bone mass to draw from as they age (El Maghraoui et al. 2010).

• **Obesity**: Increased body fat was long thought to be protective against osteoporosis (Bredella et al. 2011). Accumulating data, however, recommends that obesity-related components such as insulin resistance, hypertension, increased triglycerides, and decreased high-density lipoprotein cholesterol are all danger factors for low BMD (Bredella et al. 2011; Kim et al. 2010).

• **Cardiovascular Disease**: Cardiovascular disease and mortality are related with osteoporosis and bone fractures (Baldini, Mastropasqua, Francucci & D'Erasmo 2005).

• **Chronic Stress & Depression**: Both conditions boost cortisol production, leading to suppression of sex hormone production, increased insulin resistance, and enhanced release of inflammatory cytokines (Kiecolt-Glaser et al. 2003; Kaplan & Manuck, 2004; Berga & Loucks, 2005). All of these effects increase the danger of bone mineral loss and osteoporosis (Berga & Loucks, 2005; Bab & Yirmiya, 2010; Diem et al. 2007; Haney et al. 2007).
Other risk factors for osteoporosis include: HIV disease (Ofotokun & Weitzmann, 2010), cancer (Ewertz & Jensen, 2011; Lim, Kim, Bang, Cheon & Lee, 2007) and caffeine (Tsuang, Sun, J, Chen, L, Sun, S & Chen, S, 2006, Tucker et al. 2006) have negative effects on BMD.

Medication Use: A variety of drugs increase one’s danger for osteoporosis. These include:

- **Corticosteroids**: These immune-suppressive medicines mimic the effect of stress-induced cortisol, with all of its suppression of sex hormones, weight gain, and insulin resistance.

- **Selective Serotonin Reuptake Inhibitors (SSRIs)**: Both depression and medicines used in its treatment, such as SSRIs; enhance the risk of osteoporosis (Bab & Yirmiya, 2010).

- **“Blood thinning” Medications (Anticoagulants)**: The drug Coumadin, utilized to prevent clot formation in patients with cardiovascular disease, operates to block the useful effects of vitamin K and is related with decreased bone mineralization in a number of patients (Deruelle & Coulon, 2007). Low molecular weight heparin, an unrelated blood thinner, can also cause reduced BMC (Rezaieyazdi et al. 2009).

Osteoporosis and associated bone fractures are main public health and financial burdens. While men account for 29% of all osteoporotic fractures and 25% of osteoporosis-related costs in the United States (Burge et al. 2007).

So, it is a global public health burden and a serious concern for older adults. Over 1.5 million fractures are associated with osteoporosis each year. These fractures
result in 500,000 hospitalizations, 800,000 emergency room visits, 2.6 million physician visits, 180,000 nursing home placements, and 13.7 to 18.3 billion dollars in direct healthcare costs each year (Burge et al. 2007). For example, hip fractures are considered to be the mainly destroying consequence of osteoporosis as they are associated with severe disability and increased mortality (Cooper & Melton, 1996). By the year 2020, it is predicted that 61.4 million Americans will suffer from osteoporosis. More common in women, osteoporosis is also present in men, where it often goes undiagnosed and untreated. ("National Osteoporosis Foundation", 2002)

Both men and women are at risk for osteoporotic fractures. As osteoporosis is more common in females, most exercise-related research has focused on reducing the risk of osteoporotic fractures in women (Drinkwater, Grimston, Raabcullen & Snowharter, 1995). However, as osteoporosis is a growing problem also in males (Ringe & Dorst, 1994), more information is needed about factors influencing bone mass in this gender.

Lifestyle, genetics and environmental factors are established determinants of bone density. Osteoporotic fracture is a risk factor for subsequent long-term morbidity and mortality in elderly, especially postmenopausal women (Cooper, 1999).

Wolff’s law is a state that bone in a healthy human being or animal will adapt to the loads under which it is located (O’Connor, 2010). If loading on a particular bone increases, the bone will rebuild itself over time to become stronger to resist that sort of loading (Frost, 1994). The internal structural of the trabeculae undergoes adaptive changes, followed by secondary changes to the external cortical portion of the bone, maybe becoming thicker as a result. The contrary is true as well: if the loading on a bone decreases, the bone will become weaker caused by turnover, it is less
metabolically expensive to keep and there is no stimulus for continued remodeling that is necessary to maintain bone mass (Wolff, 1986).

The remodeling of bone in answer to loading is reached via mechanotransduction, a process through which forces or other mechanical signals are changed to biochemical signals in cellular signaling (Huang & Ogawa, 2010). Mechanotransduction leading to bone remodeling involves the steps of mechanocoupling, biochemical coupling, signal transmission, and cell response (Duncan, & Turner, 1995). The specific effects on bone structure depend on the duration, magnitude and rate of loading, and it has been found that only cyclic loading can induce bone formation (Duncan, & Turner, 1995).

There are various mechanisms for the alteration of mechanical force to biochemical responses for enhanced bone formation. Factors associated to achievement of best BMD and BMC have not been known clearly. Though, four factors which play major roles are Genetics, Exercise, Hormonal status, and Nutrition. Although genetic influences seem to have the maximum impact; but exercise, hormones, and nutrition are able to modify the high bone mass obtained or maintained. Especially, exercise has been associated with higher BMD. Therefore, the most efficient exercise protocol for reaching and maintaining the peak BMD has not been firmly recognized (Munoz, de la Piedra, Barrios, Garrido & Argente, 2004; Nordström et al. 2005).

Physical activities, predominantly weight-bearing exercises are believed to supply the mechanical stimuli or 'loading' importance for the maintenance and improvement of bone healthliness, whereas physical inactivity has been implicated in bone loss and its related health expenditures. Both, aerobic and resistance training
exercise, can give weight-bearing stimulus to bones, yet research indicates that resistance training may have a more profound site specific effect than aerobic exercises. High-intensity resistance training, in contrast to traditional pharmacological and nutritional approaches for improving bone health in older adults, have the added benefits of influencing many risk factors for osteoporosis, including improved strength, balance and increased muscle mass (Ginty et al. 2005).

The effect of exercise on BMD depends on the kind of activity engaged in. Sports with high impact loading appear to have an affirmative effect in promoting bone mineralization, whereas those with low impacts may have negative or no effects (Egan, Reilly, Giacomoni, Redmond, & Turner, 2006).

The study of Tsuzuku, Shimokata, Ikegami, Yabe, & Wasnich, (2001) on young male power lifters, recreational trainees and controls recommended that high-intensity resistance training is useful for increasing BMD, but low-intensity resistance training is not.

Tsuzuku, Ikegami, & Yabe, (1998) established a significant relationship among lumbar spine BMD and powerlifting performance. These results advocate that high-intensity resistance training is efficient in increasing the lumbar spinal column and whole body BMD.

Studies in males have reported that physical training leads to a boost of BMD, mainly in the highly stressed components of the skeleton, such as in the playing arm of tennis players (Haapasalo et al. 1996).

The study of Andreoli et al. (2001) has revealed that sportspersons, particularly those participated in high-impact sports, have significantly higher total BMD than
controls. These results imply that the kind of sport activity might be a key factor in achieving a high peak bone mass and decreasing osteoporosis danger.

Mechanical loads are vital for the growth and maintenance of bones. Gymnasts and runners present excellent models of loading in the human body. Gymnasts can experience earth reaction forces further than 12 times their body weight, while runners only experience earth reaction forces of 3-5 times their body weight. A study by Robinson et al. (1995) established the areal BMD of gymnasts at both the hip and the spine was 30-40% higher than in runners. Another study demonstrated that during a training period, gymnast amplify their aBMD while runner’s aBMD does not raise (Taaffe, Robinson, Snow & Marcus, 1997). A study discovered that during the off season, when gymnasts have not performed training, their aBMD declined significantly (Laing et al. 2002). These studies emphasize the adaptive reaction of bone to loading in the human skeleton.

Platen et al. (2001) concluded that mechanical loads have strong effects on bone adaptation. Mostly dynamic sports with short, high, and multidimensional loads have the strongest effects on bone creation, independent of training quantity.

The results of study of Nilsson, Ohlsson, Sundh, Mellström, & Lorentzon, (2010) has revealed the amount of mechanical loading caused by kind of physical activity was mainly related with trabecular microstructure, whereas period of prior physical activity was mostly associated to factors reflecting cortical bone size in weight-bearing bone.

Results of the study of Sööt, Jürimäe, T., Jürimäe, J., Gapeyeva, & Pääsuke, (2005) have recommended muscle strength and anthropometrical factors were related with female's leg BMD.
It is now generally accepted that physical activity is useful to bone. BMD has been showed to be higher in sportspersons than in more inactive persons (Block, J., Genant & Black, D. 1986; Nilsson & Westlin, 1971), and weight-bearing activities for instance weight training and gymnastics look to be more efficient than endurance activities such as long distance running, and non weight bearing activities such as swimming (Heinonen et al. 1995; Fehling, Alekel, Clasey, Rector & Stillman, 1995; Kasper, 1992). A growing body of evidence recommends that higher BMD may be a function of greater muscle strength (Block et al. 1989; Pocock et al. 1989; Sinaki et al. 1986).

Cross sectional studies show that sportspersons, particularly those who are strength trained, commonly have greater BMD than non-athletes, and that highest strength levels and muscle mass associate with bone density.

Strength training or sports events like throwing and jumping are capable of more successfully add to BMD due to the application strain amounts and rates of force development closer to the optimum for stimulating bone remodeling (Whittington et al. 2009).

A study on elite junior USA weightlifters demonstrated there was very strong associations among explosive strength (snatch and clean & jerk), basic strength (1 RM squat) and measures of BMD. This study also indicated that the BMD values of the spine and femoral neck of junior weightlifters were significantly greater than adult reference data and inactive subjects (Conroy et al. 1993).

It is recommended that the most useful form of exercise for the skeleton is dynamic, weight-bearing activity. Studies using controlled external loading in animal models have established that osteogenesis is maximal with high-magnitude strains
applied at a high rate and that relatively few strain cycles are needed (O'Connor, Lanyon & MacFie, 1982; Raab-Cullen, Akhter, Kimmel & Recker, 1994; Rubin & Lanyon, 1984). If these principles are applied to humans, activities such as weight training, sprinting, and jumping be supposed to have a greater consequence on bone mass than distance running. This idea has been sustained by some researchers (Heinrich et al. 1990; Kelly, Pocock, Sambrook & Eisman, 1989) but not others (Snow-Harter, Bouxsein, Lewis, Carter & Marcus, 1992).

It is not known whether these adaptations are induced by muscle pull or by mechanical or other factors. Experiments with animals exposed that new bone formation depends less on length of mechanical pressure and more on its degree, rate, and distribution-especially strains of high rate and magnitude and of unusual distribution stimulated new bone formation (McLeod & Rubin, 1994; Rubin & McLeod, 1995). Thus, it can be assumes that physical activities with dynamic and impact loading models with variable stimuli demonstrate the strongest osteogenic effects (Chilibeck, Sale & Webber, 1995). Though, advantages of one exercise program over another are still uncertain. Human exercise studies have made mixed results. Only a small number of studies are accessible on the osteogenic effects of long-term physical training on different skeletal sites in sportsmen of different sports (Conroy et al. 1993; Haapasalo et al. 1996). Moreover, only a few results have been issued on the effects of mechanically complex team sports with variable stimuli on BMD (Calbet, Herrera & Rodriguez, 1999; Nordström, Thorsen, Bergström & Lorentzon, 1996; Wittich et al. 1998). Consequently, many open questions stay about the specific in vivo effects of different mechanical loads on bone in men.

The effects of anthropometric factors with their more or less global influences on bone have been investigated in some studies. The consequences of these
investigations most often exposed an affirmative effect of total body weight, BMI, LBM, body fat, and height on BMD, with, however, a large difference in correlation coefficients (Christensen, M., Christiansen, C., Naestoft, McNair & Transbol, 1981; Pocock et al. 1989; Wüster et al. 1992). The associations between anthropometric variables and BMD might partially be clarified by their mechanical impacts on bone (Lanyon, 1992). Body weight, for example, provides resistance that muscles are required to overcome for work and play (Frost, 1999). It remains vague; however, whether BMD is determined via body weight by itself or with single elements of body composition.

Hence, the researcher is interested to review: (a) to investigate of bone mineral density at three sites of the skeleton in male athletes of different high-intensity sports i.e. non-weight bearing and weight bearing exercises - athletes who chronically train in different sports and thus have differing amounts of mechanical loading on the skeleton; and (b) to evaluate the anthropometric variables, motor fitness variables and BMI as predictors of bone mineral density among sportsmen (volleyball, throwing, bodybuilding and swimming).

**Statement of the Problem**

The purpose of the study was to find out; "Anthropometric Variables, Motor Fitness Variables and BMI as Predictors of Bone Mineral Density among Sportsmen"

**Objectives of the study**

1. To assess of anthropometric variables, motor fitness variables and BMI among sportsmen.
Introduction

2. To assess of Bone Mineral Density among sportsmen participating in weight bearing activities and non-weight bearing activities.

3. To predict the bone mineral density (BMD), by anthropometric variables, motor fitness variables and BMI if any.

4. To predict the bone mineral density (BMD), by anthropometric variables, motor fitness variables and BMI among Sportsmen in weight bearing activities viz volleyball, throwing and body Building.

5. To predict the bone mineral density (BMD), by anthropometric variables, motor fitness variables and BMI among Sportsmen in non-weight bearing activities viz swimming.

Delimitations

1. The study was delimited to 100 Iranian sportsmen.

2. Assessment was delimited to only select sportmen for the national level.

3. The study was delimited to the collection of data only in four groups of sportmen (volleyball, throwing, swimming and bodybuilding).

4. The study was delimited to analysis of bone mineral density by the DXA method.

5. The bone mineral density was delimited to the lumbar bones (L2-L4), neck of the femur and wrist.

6. The study was delimited to analysis of 12 anthropometric variables and BMI.

7. Only the following motor fitness variables were assessed: Speed (35 meters speed Test), Power (Standing Long Jump and Vertical Jump Tests), Strength (Head Press and Squat 1RM Tests) and Aerobic Endurance (Harvard Step Test).
Introduction

Limitations

1. Researcher was not able to control the diet of the subjects.

2. Researcher was not able to control the life’s situation of the subjects.

3. Researcher was not able to control Hormonal disorders of the subjects.

4. Researcher was not able to control genetics symptoms of the subjects.

Hypotheses

**H1**: Only few anthropometric variables, motor fitness variables and BMI best predict bone mineral density (BMD) among sportsmen.

**H2**: Only few anthropometric variables, motor fitness variables and BMI best predict bone mineral density (BMD) among sportsmen participating in weight bearing sports, viz volleyball, throwing and bodybuilding.

**H3**: Only few anthropometric variables, motor fitness variables and BMI best predict bone mineral density (BMD) among sportsmen participating in non-weight bearing sports, viz swimming.

**H4**: Only few anthropometric variables, motor fitness variables and BMI best predict bone mineral density (BMD) among sportsmen participating in weight bearing sports, viz volleyball.

**H5**: Only few anthropometric variables, motor fitness variables and BMI best predict bone mineral density (BMD) among sportsmen participating in bodybuilding.

**H6**: Only few anthropometric variables, motor fitness variables and BMI best predict bone mineral density (BMD) among sportsmen participating in throwing.
Definitions of the Terms

• **Anthropometry:**

  Anthropometry is defined as the knowledge of the assessment of a person's physical parameters such as height, weight, etc. The field that deals with the physical dimensions, proportions, and composition of the human body, plus the study of connected variables that concerns them (Marfell-Jones, 1991).

• **Stretch Stature (Height):**

  It is a measurement of the maximum vertical distance from the floor to the highest point of the head (Marfell-Jones, 1991).

• **Body Mass (Weight):**

  It is the total weight of body mass of a person (Marfell-Jones, 1991).

• **Sitting Height:**

  It is a measurement of the distance from the highest point on the head to the base sitting surface (Marfell-Jones, 1991).

• **Arm Span:**

  The distance from the left to the right dactylion when the palms are facing forward and the outstretched arms are abducted to the horizontal. It is the physical measurement of the length from one end of an individual's arms (measured at the fingertips) to the other when raised parallel to the ground at shoulder height at a 180 degree angle (Marfell-Jones, 1991).
• **Arm Length (Acromiale - Radiale):**

   It is the length of the arm from acromion -outer edge of the shoulder blade-point of shoulder joint to radius -upper and lateral border of the head of radius- (Marfell-Jones, 1991).

• **Forearm Length (Radiale - Stylion):**

   It is the length of the forearm from radius -upper and lateral border of the head of radius- to styloid process -the lateral surface of the distal radius bone- (Marfell-Jones, 1991).

• **Hand Length (Midstylion - Dactylion):**

   It is the length of the hand from mid-stylion -at the distal wrist crease- to the dactylion -the tip of the middle finger- (Marfell-Jones, 1991).

• **Thigh Length (Trochanterion - Tibiale Laterale):**

   It is the length of the thigh from trochanterion -the most superior point on the greater trochanter of the femur- to the tibiale laterale -the most proximal point of the lateral border of the head of the tibia- (Marfell-Jones, 1991).

• **Tibial Length (Tibiale Mediale - Sphyrion Tibiale):**

   It is the length of the tibia from tibiale mediale -the most proximal point of the medial border of the head of the tibia- to the sphyrion tibiale -the most distal tip of the medial malleolus- (Marfell-Jones, 1991).

• **Humerus Breadth (Biepicondylar):**

   The distance between medial and lateral epicondyles of the humerus when the arm is raised forward to the horizontal and the forearm is flexed to a right angle at the elbow (Marfell-Jones, 1991).
• **Wrist Breadth (Bistyloid):**

   The distance between medial and lateral parts of wrist when the forearm is resting on a table or the subject’s thigh and the wrist is flexed to an angle of about 90° (Marfell-Jones, 1991).

• **Femur Breadth (Biepicondylar):**

   The distance between medial and lateral epicondyles of the femur when the subject is seated and the leg is flexed at the knee to form a right angle with the thigh (Marfell-Jones, 1991).

• **Motor fitness variables:**

   Motor Fitness refers to the capability of an athlete to perform effectively at their particular sport. The components of motor fitness are: agility, balance, co-ordination, power which entails speed and strength and finally reaction time (Johnson & Nelson, 1969).

• **Speed:**

   Speed is the ability to move quickly across the ground or move limbs rapidly to grab or throw (Wood, 2011). speed of movement is the rate at which a person can propel the body, or parts of body, between two points (Johnson & Nelson, 1969).

• **Power:**

   Power may be defined as the ability to release maximum force in the fastest possible time (Johnson & Nelson, 1969). Power is defined as the amount of work performed per unit of time. It is an element of skill-related fitness that is needed to excel in athletic performance (Luann Voza, 2013). Moreover, the ability to exert a
maximal force in as short a time as possible, as in accelerating, jumping and throwing implements (Wood, 2011).

- **Strength:**

  Strength may be defined generally as the muscular force exerted against movable and immovable objects, it is best measured by tests that require one maximum effort for a given movement or position (Johnson & Nelson, 1969). Muscular strength is defined as the ability of a muscle or muscle group to exert force to overcome the most resistance in one effort. The measurement of strength is based on the amount of weight lifted one time (Luann Voza, 2013).

- **Aerobic Endurance:**

  Cardiovascular endurance, aerobic fitness, or stamina, is the ability to exercise continuously for extended periods without tiring. A person's aerobic fitness level is dependent upon the amount of oxygen which can be transported by the body to the working muscles via the lungs and blood system, and the efficiency of the muscles to use that oxygen (Wood, 2011).

- **Body Mass Index (BMI):**

  BMI is a simple index of weight-for-height that is commonly used to classify underweight, overweight and obesity in adults. It is defined as the weight in kilograms divided by the square of the height in meters kg/m$^2$ (World health Organization, Adapted 2004).

- **Bone Mineral Density:**

  Bone mineral density is a medical term referring to the amount of matter per square centimeter of bones (g/cm$^2$). Bone density is used in clinical medicine as an
indirect indicator of osteoporosis and fracture risk. (Bone Density at the US National Library of Medicine, 2011)

Table 1.2: Definitions of WHO based on Bone Mineral Density levels

<table>
<thead>
<tr>
<th>Normal</th>
<th>Bone density is within 1 SD (+1 or −1) of the young adult mean.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low bone mass Osteopenia</td>
<td>Bone density is between 1 and 2.5 SD below the young adult mean (−1 to −2.5 SD).</td>
</tr>
<tr>
<td>Osteoporosis</td>
<td>Bone density is 2.5 SD or more below the young adult mean (−2.5 SD or lower).</td>
</tr>
<tr>
<td>Severe (established) osteoporosis</td>
<td>Bone density is more than 2.5 SD below the young adult mean, and there have been one or more osteoporotic fractures.</td>
</tr>
</tbody>
</table>

Source: "NIH osteoporosis and related bone disease", updated 2012

• **DXA Method:**

  Dual-energy X-ray absorptiometry (DXA, previously DEXA) is a means of measuring bone mineral density (BMD). Dual-energy X-ray absorptiometry is the most widely used and most thoroughly studied bone density measurement technology ("Wikipedia, the free encyclopedia", updated 2014).

• **Sportsmen or athletes:**

  A person possessing the natural or acquired traits, such as strength, agility, and endurance that are necessary for physical exercise or sports, especially those performed in competitive contexts ("The American Heritage Dictionary", Updated
or a person trained or gifted in exercises or contests involving physical agility, coordination, stamina, or strength ("Random House Kernerman Webster's College Dictionary", 2005).

**Significance of the Study**

1. Assessment of bone mineral density (BMD) is not possible everywhere and needs a special instrument and equipment. For instance DXA, etc are not portable, also is very costly. This study wants to find a simple and accessible method to predict Bone Mineral Density (BMD) everywhere by anthropometric variables, motor fitness variables and BMI and without need to special and expensive tools.

2. The present study may help the researchers, physicians, sport trainers and athletes to understand the effective and dominant factors that indicate bone mineral density.