Chapter One

INTRODUCTION
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The necessity for most people to engage in challenging physical activity has disappeared due to the dramatic changes in the lives of people in industrialized countries during recent times. A host of hypo kinetic diseases have become manifest among individuals irrespective of age and sex. Thus, intentional physical activity has become an important component of a healthy life style.

Advancement in technology has paved the way for modern life style which is predominantly less active and more stressful. A large number of inactivity related diseases have put serious threat on the wellbeing of human beings. Many of the diseases interfere in day to day functioning of man. These illnesses are considered more serious as it affects the functional capacity and lays huge burden on health care expenditure. It is therefore most essential to find non pharmacological ways and means to deal with these hordes of disabling conditions.

It is an established fact that the segment of ageing population is considerably increasing due to low mortality rate in past few decades. Disease free elderly community is an asset to the society, whereas disease struck elderly population is a liability. Chronic diseases like diabetes, hypertension, cancer etc. are believed to be interfering in the quality of their life. Such conditions eventually lead to psycho-somatic disorders which are difficult to cure.
Debate persists about the time and circumstances of the emergence of homosapiens, but it is commonly recognized that the emergence of human beings was intimately related to progressive molecular changes in genes affecting brain functions of closely related non human primates. The evaluation of the brain meant not only greater brain capacity, progressive mastery of language, and more refined intelligence but also growing control over an expended movement repertoire. From the research of paleontologists, anthropologists, anatomists, archeologists, and molecular biologists, the main events in the evolution of human species can be briefly outlined with an emphasis on those that have implications for physical activity. Human body is basically engineered for movement. The neurological, muscular, and skeletal systems all work together to produce human movement, with forces being produced and transmitted within the musculoskeletal system (Bouchard, Blair and Hasell, 2007).

Osteoporosis

Osteoporosis is a disease of the skeletal system that is characterized by low bone mass and micro architectural deterioration of bone tissue leading to enhanced bone fragility and increased fracture risk. It is largely a silent disease producing no symptoms until it is manifested clinically in the form of overt fractures. Osteoporosis actually means “porous bones”. It exists in a few different forms, all of which are characterized by a measurable loss of bone mass. The bone loss is the effect of an imbalance between bone resorption and bone deposition: resorption outpaces production. The maintenance of homeostasis often depends on a delicate balance between competing, opposing activities. The maintenance of bones is no exception (Clark, 2004).
An overview of bones

The skeleton is formed from two of the strongest and most supportive tissues in the body: cartilage and bone. In embryos, the skeleton is primarily made of hyaline cartilage, but in the young child most of the cartilage will be replaced by bone. Most bones (except flat bones) develop using hyaline cartilage structures as their “models”. This process of bone formation, or ‘ossification’, involves two major phases. First, the hyaline cartilage model is completely covered with bone matrix by bone forming cells called ‘osteoblasts’. Then, the enclosed hyaline cartilage model is digested away, opening up a medullary cavity within the newly formed bone. By birth or shortly after, most hyaline cartilage models have been converted to bone except for two regions: the articular cartilages and the epiphyseal plates.

Bones are remodeled continually in response to changes in two factors: (1) Calcium levels in the blood and (2) the pull of gravity and muscles on the skeleton. When blood calcium levels drop below homeostatic levels, the parathyroid gland is stimulated to release parathyroid hormone (PTH) into the blood. PTH activates ‘osteoclasts’, giant bone destroying cells in bones, to break down bone matrix and release calcium ions into the blood. On the other hand when blood calcium levels are too high, calcium is deposited in bone matrix as hard calcium salts. Bone remodeling is essential if bones are to retain normal proportions and strength during long bone growth as the body increases in size and weight. It also accounts for the fact that bones become thicker and form large projections to increase their strength in areas where bulky muscles are attached. At such sites, osteoblasts lay down new matrix and become trapped within it to form osteocytes or mature bone cells (Marieb, 2000).
Bones are made up of proteins, minerals, and vitamins. Minerals present in bones include calcium, potassium, manganese, magnesium, silica, iron, zinc, selenium, boron, phosphorus, sulfur, chromium, and many others. In order for bones to absorb the minerals, vitamin D must be present in the diet.

Bone is a vital connective tissue that makes up the solid foundation for the human body. As the primary function of bone is to make possible efficient locomotion of human beings, it has to resist continuous mechanical load without breaking. To enable this, bone optimises its structure with subtle adaptations to maintain rigidity along with lightness. However, decrease in bone mass is inevitable and physiological with age, leading eventually to skeletal fragility. If the bone mass drops to a critical level below which fracture risk is substantially increased, the state is considered pathological (osteoporosis).

Maximum bone mass is one of the factors determining fractures and osteoporosis more prevalent in adults. Remodeling and bone formation continues from birth to about 30 years of age when the osteoblasts and osteoclasts are active (Nazarian, et. al., 2009)

Bone mineral Density and its assessment

Bone mineral density (BMD) is a medical term referring to the amount of matter per square centimeter of bones. It is measured by a procedure called densitometry which is often performed in the radiology or nuclear medicine departments of hospitals or clinics. A BMD test measures the density of minerals in bones using a special X-ray, computed tomography (CT) scan, or ultrasound. The measurement is painless and non invasive and involves minimal radiation exposure. This information in terms of g/cm² is used to estimate the strength of bones (Wikipedia, 2010).
In 1994, the world health organization (WHO) proposed guidelines for the diagnosis of osteoporosis based on BMD measurements. According to the WHO criteria, osteoporosis is defined as a BMD of 2.5 or more standard deviations below the peak mass of a young, healthy, sex and race matched reference population (Shin, et. al., 2005).

BMD is determined mainly by genetic factors; however nutrition, physical activity, mechanical loading, and body composition also contribute to a varying extent throughout life. A positive correlation has been reported between muscle strength and local BMD in some cross-sectional studies, but such a relationship has not been found by some authors (Tamci, et. al., 2009).

According to Huang, et. al. (2003) measurements of bone development in human studies are typically limited to non invasive radiography or serum bone marker assays due to ethical issues. It is difficult to investigate the effects of exercise mode on bone by using current accessible techniques.

The knowledge of bone mechanisms and of some other factors that might influence peak bone mass has become more and more important in particular when individuals reach old age with a strong and dense skeleton as a result of high peak bone mass acquisition during adolescence (Fonseca, Franca & Paragh, 2008).

Until recently, it was mostly agreed that bone mineral measurements were only of value in research upon groups of people and that a measurement on an individual was of little use. This was partly because of the big overlap between ‘normal’ and ‘osteoporotic’ subjects, but also because there were few measures that could be expected to bring any benefit. Opinion is now shifting and there may be cases for some degree of screening to
identify subjects with a lower than average bone mass so that prophylactic measures may be recommended (Tothill, 1989).

Dual X-ray Absorptiometry (DXA) is the most widely used method for the measurement of bone mineral content (BMC) and BMD. The radiation dose was comparable to daily background radiation exposure and the precision was found to be good and stable in clinical use by Vainionpa (2007).

Many different techniques are available for noninvasive determination of BMD, including DXA for both peripheral and central sites, quantitative computed tomography (QCT), quantitative ultrasound (QUS), and radiographic absorptiometry. Among these techniques, epidemiologic and pharmaceutical trials in which monitoring of BMD was required have relied almost exclusively on DXA measurements.

The ability of DXA to monitor BMD has been well documented in epidemiologic and pharmaceutical trials. However, its application to monitor patients in clinical practice has been subject to recent controversies. Despite these controversies, most clinical centers rely on DXA for monitoring of patients, and therefore guidance is needed. Lenchik, Kiebzak and Blunt (2002) reported the positions developed by an expert panel of the International Society for Clinical Densitometry on the use of densitometry for the serial measurement of bone mass for monitoring change in BMD. The panel found DXA to be a precise method of measuring change in BMD.

Physical activity and bone health

Osteoporosis is a major public health problem, affecting millions of people worldwide. The associated health care costs are growing in parallel with increases in elderly populations, and it is expected that the number of osteoporotic fractures will
A considerable increase over the next few years. Policy makers and health professionals need to consider the economic and public health implications of osteoporosis and identify efficient prevention and management methods to reduce the increasing burden of the condition on already stressed health care systems.

The best way to address osteoporosis is prevention. Some interventions to maximize and preserve bone mass have multiple health benefits and are cost-effective. For example, modifications to diet and lifestyle can help to prevent osteoporosis, and could potentially lead to a significant decrease in fracture rates; and exercise is a valuable adjunct to programmes aimed at alleviating the risks and symptoms of osteoporosis. Despite the existence of medical intervention for osteoporosis, physical activity is highly recommended at the first step in its prevention. Practicing exercise at a young age helps maximize the mineral density of bones while they are still growing and maturing, and continuing to exercise minimizes bone loss later in life. Encouraging physical activity at all ages is therefore a top priority to prevent osteoporosis (Chan, Anderson, and Lau, 2003).

Physical activities and sport provide several beneficial effects on human body and mind. Various systems in the human body respond differently to varying degrees of physical activities. Intensity, volume and frequency are essential parameters to assess the benefits physical activities on human biological systems. Adolescent’s indulgence in physical activities have cumulative effects which are obvious during old age.

The use of exercise to maintain bone health throughout life and ultimately prevent osteoporosis related fractures has received substantial research attention in recent years (Vainionpa, 2007). Although genetic factors appear to have the greatest impact, exercise,
hormonal status, and nutrition can modify the modelling and remodeling of the bone to optimise and maintain peak bone mass. The desired outcomes of all treatment regimens are to improve bone strength. Physical exercise, especially weight bearing activity, has been reported to have beneficial effects on the skeleton in both adolescents and the elderly.

Mahabalaraju (2007), a renowned orthopedician opines that the status of bone health has to be regularly examined. As age advances, bones become porous and the fact is revealed only when there is an associated fracture. Although there are medications in case of bone becoming brittle, but these pharmacological agents only prevent further worsening of the condition. Therefore, physicians suggest various preventive measures for maintaining bone health. Focus of attention is mainly towards diet and physical activities.

Exercise has been recommended as a non-pharmacological approach for maximizing BMD during the younger years as well as improving bone density by increasing and/or preventing the loss of bone during the older years. Exercise may be especially appropriate, since it is a low - cost intervention that is available to most of the general public. However, training studies examining the effects of exercise on BMD in men have led to conflicting results. Among the studies cited in a meta analysis conducted by Kelly, Kelly and Tran (2000), only 39% of the sites assessed were reported as statistically significant and positive when compared with a control group.

Bone mass accumulates throughout childhood and into young adulthood. During this time, an increase in bone resorption and/or decreases in bone formation can lead to less than optimal peak bone mass. Attaining higher peak values may lend protection as age related bone loss occurs. Identifying contributors and disrupters to the process of skeletal
development may aid in the prevention and treatment of osteoporosis (Creighton, et. al., 2001). Physical exercise and sport training are important factors in the acceleration and maintenance of BMD. The mechanism of the beneficial effects of exercise on bone metabolism has been the focus of intensive research.

Muscular performance and BMD

According to the theory of mechanostat the bone-muscle interaction plays a dominant role. Thus, exercise should mostly affect bone indirectly via the muscle interface. In this context, the osteo-anabolic relevance of habitual physical activity and non athletic exercise is still under discussion. Skeletal muscle contraction forces generate large reaction forces during normal activity and such forces are thought to have a trophic or adaptive effect on bone mass, locally (Dixon, et, al., 2005)

There are many discrepancies as to the relationship of BMD to the muscular power and body composition, mainly to determine what factors are most associated to the BMD. The determination of what type of physical activity is the ideal to increase the bone mass peak during the adolescence or even aiming to keep it later in the adult years is quite important in order to prevent and possibly treat osteoporosis (Cadore, Brentano and Kruel, 2005). This argument is further supported by Rahnama, et. al. (2009) who opines that the risk of osteoporosis is affected by the peak bone mass attained before the age twenty. Majority of the bone mass accrual is marked between eleven and forty years of age in girls.

It is widely accepted that physical activity benefits the musculoskeletal system but the mechanisms affecting bone mass and density that are set off by physical activity in general and mechanical loading in particular are still poorly understood (Kemmler, et. al.,
Further, it is increasingly accepted that the roots of adult osteoporosis are cultivated in childhood, and the WHO agrees that the debate around non communicable diseases must be redirected toward prevention (Kerry, et. al., 2003)

The BMD might be influenced by several variables such as body mass, functional loading, family history of osteoporosis, nutritional status, training intensity and frequency, and calcium balance.

Dearth of knowledge

According to Daly, Rich and Klein (1997) knowledge concerning long term effects of physical activity on bone formation in children is incomplete and inadequate. Comparison of athletes participating in different sports can provide valuable information but the results must be interpreted carefully because of the cross-sectional design and the selectivity of the samples under study. However, experimental studies examining the affect of physical activity during childhood and adolescence support the hypothesis that physical activity has a beneficial influence on the skeleton during growth (Langendonck, et. al., 1996)

Duppe, et, al. (1997) studied on the effect of exercise programs to increase BMD and reported beneficial as well as negative effects. Ishikawa and Sakuraba (2009) reported that the BMD of endurance athletes such as marathon runners is lower than that of non-athletes. Bone metabolism movement varies depending not only on the type, frequency and intensity of sport and physical activity, but also on age and sex.

Several studies have indicated that higher BMD may be a function of greater muscle strength. (Fonseca, et. al., 2009, & Tamci, et. al., 2009). In spite of conflicting
results, recently, some studies reported a positive relation between bone density sites and the strength of distant muscles that are not attached to these bones. Further, Tamci, et. al., (2009) suggests that the effect of muscle strength on bone mass is not only site specific but more likely it is systemic. Relationship between muscle strength and BMD is generally reported among sedentary persons and those with low to moderate levels of physical training; however, little or no relationship is seen between BMD and muscle strength among highly trained persons. Conflicting results about the relationship between muscle strength and BMD are attributed to confounding variables such as calcium intake, weight, height and body mass index. Moreover, researchers admitted that there are no studies investigating other factors that may influence the relationship between strength and BMD among highly trained individuals.

Genetic (sex, age, body size and ethnicity) risk factors for osteoporosis cannot be modified but it is possible to change variables like lifestyle and physical activity to stimulate greater accumulation of peak bone mass. Sports participation during childhood and adolescence, especially before the pubertal growth spurt, promotes bone mass accumulation, i.e. gain in total BMC, and geometrical changes in bone size and shape leading to higher bone mass and stronger bones in adult life. In fact, epidemiological studies indicate that bone size is related to fracture risk when examined in relation to body size in children, and participation in sports prior to puberty promotes bone hypertrophy, i.e. physically active pre-pubertal children appear to develop bone of greater size than their sedentary peers, although this effect is confined to the loaded regions (Amelia, et. al., 2009).
Existing knowledge do not clearly recommend the type of physical activity to be performed for high bone mineral acquisition. The load parameters for determining physical activity counting intensity, volume, frequency and patterns (for loading) are considered the most important predictors of high BMD. Although well documented reviews have been published in postmenopausal women, less is known about the effects that exercise programme and sports participation may have on bone mass in young adult women at premenopausal age. Since there has been no published data on the influence of loading patterns and muscular performance on BMD of trained athletes in the Indian perspective, this study aimed to produce some information in this respect.

**THE STATEMENT OF PROBLEM**

The purpose of study was:

1. To examine the differences in BMD among athletes and non athletes on the basis of loading patterns; and sports disciplines.
2. To assess the influence of muscle performance on BMD.

**HYPOTHESES**

1. BMD of female athletes with different loading patterns and non-athletic control differ significantly from each other at arms, legs, femoral neck, pelvis, spine, dominant hand forearm and total body.
2. BMD of male athletes with different loading patterns and non-athletic control differ significantly from each other at arms, legs, femoral neck, pelvis, spine, dominant hand forearm and total body.
3. BMD of female athletes indulged in different sports disciplines and non athletes differ significantly at arms, legs, femoral neck, pelvis, spine, dominant hand forearm and total body.

4. BMD of male athletes indulged in different sports disciplines and non athletes differ significantly at arms, legs, femoral neck, pelvis, spine, dominant hand forearm and total body.

5. Female athletes possessing high, average & low static strength, measured in terms of dominant hand grip strength, and non athletes differ significantly in BMD at respective forearm.

6. Male athletes possessing high, average & low static strength, measured in terms of dominant hand grip strength, and non athletes differ significantly in BMD at respective forearm.

7. Female athletes possessing high, average & low explosive strength, measured in terms of vertical jump, and non-athletes differ significantly in BMD at legs.

8. Male athletes possessing high, average & low explosive strength, measured in terms of vertical jump, and non-athletes differ significantly in BMD at legs.

9. Female athletes possessing high, average & low muscular endurance, measured in terms of flexed arm hang, and non-athletes differ significantly in BMD at arms.

10. Male athletes possessing high, average & low muscular endurance, measured in terms of pull ups, and non-athletes differ significantly in BMD at arms.

11. Female athletes possessing high, average & low dynamic strength, measured in terms of sit ups and non-athletes differ significantly in BMD at femoral neck.
12. Male athletes possessing high, average & low dynamic strength, measured in terms of sit ups and non-athletes differ significantly in BMD at femoral neck.

13. Female athletes possessing high, average & low muscle performance capacity; measured in terms of grip strength, flexed arm hang, vertical jump and sit ups; and non-athletes differ significantly in total body BMD.

14. Male athletes possessing high, average & low muscle performance capacity; measured in terms of grip strength, pull ups, vertical jump and sit ups; and non-athletes differ significantly in total body BMD.

15. Muscular performance in terms of grip strength, vertical jump, pull ups and sit ups predicts total body BMD in trained female athletes.

16. Muscular performance in terms of grip strength, vertical jump, pull ups and sit ups predicts total body BMD in trained male athletes.

**THE DELIMITATIONS OF STUDY**

The study was delimited to following aspects:

1. The study included 30 boys and 40 girls of Thiruvananthapuram, Kerala within the age group of 15 to 19 years.

2. Measurement of BMD was carried out with Dual Energy X-ray Absorptiometry (DXA) provided by Lunar Prodigy.

3. BMD sites included in the study were legs, femoral neck, pelvis, spine, arms, dominant hand forearm and total body.
4. Muscular performance capacity was delimited to static strength, explosive strength, muscular endurance and dynamic strength.

5. Self structured questionnaire (Appendix C & D) included details on age, education, sports participation, diet practices, medication details, fracture incidents (if any), smoking, alcohol consumption, weight reduction strategies (if any), menarche & menstrual cycle (for girls only).

THE LIMITATIONS OF STUDY

Following were the limitations to study:

1. Involvement of athletes in activities contrary to their respective predominant loading pattern could not be controlled.


3. The responsiveness of skeleton to mechanical loading varies during different stages of life, and its association with changes in body’s endocrine environment was not considered.

4. Intervention in terms of body types, thickness of tissue overlying the bone and other extraneous factors were not controlled.

5. False high bone density due to acute micro trauma just prior to testing could not be excluded.

6. Influence of muscle fiber distribution, muscle hypertrophy and physical conditioning on muscle performance was not considered.

7. Differences in BMD associated with maturational and genetic factors could not be controlled.
THE DEFINITION AND EXPLANATION OF TERMS

1. Physical activity

Physical activity is defined as any bodily movement produced by skeletal muscles that result in caloric expenditure (Rahl, 2010).

2. Physical fitness

Physical fitness is the body’s ability to perform specific tasks or activities for a prolonged duration without experiencing undue physical stress or fatigue (Rahl, 2010).

3. Trained athletes

Individuals possessing natural or acquired traits that are necessary for sports and games, especially those performed in competitive contexts (Dictionary).

4. Loading patterns

Mechanical loading during physical activity produces strains within bones. It is thought that these strains and strain rates provide the stimulus for the structural adaptation of bones. Application of strain may be direct or indirect and it is referred as loading patterns in this context.

5. Mechanical loading

Mechanical load acting on the biological structures of the human locomotor system during sport is one possible stimulus to maintain and/or increase the strength of biological material (Zatsiorsky, 2000).

6. Impact loading

Impact loading is a form of loading that occurs as the foot contacts the ground (Crowell, et. al., 2010). When loads are applied suddenly and when the loads are
applied as impact loads the resulting stresses induced on the human body are much higher than if the loads are applied gradually.

According to Grimston et. al. (1993) impact loading includes sports producing ground reaction force greater than or equal to three times body weight. In the present context kabaddi, taekwondo, middle & long distance running, volleyball, boxing and gymnastics were included as impact loading sports.

7. Active loading

Active loading in the present context refers to mechanical stresses included in various sports which do not have direct impact on the skeleton of athletes involved in this study.

Grimston et. al. (1993) further suggests that the non gravitational sport such as swimming come under active loading sports. In the present context cycling and swimming were included as active loading sports.

8. High impact Sports

An activity or sport characterized by intense and/or frequent wear and trauma of weight-bearing joints—foot, knee and hip (medical dictionary).

9. Low impact sports

Any sport with minimal wear and trauma to weight-bearing joints, especially of the foot, knee, and hip is referred as low Impact sports (medical-dictionary).

10. Moderate impact sports

A recreational activity or sport in which there is relatively intense wear and trauma of weight-bearing joints, especially of feet, knees, hips (medical-dictionary).
11. Body composition

Body composition is the term used to describe the different components that, when taken together, make up a person's body weight (sportsmedicine.about.com). It is the body's relative amount of fat to fat-free mass. It refers to the constituents of body - lean mass, fat mass, and water.

12. Lean body mass

The lean body mass is that part of the body including all its components except neutral storage lipid; in essence, the fat-free mass of the body (Medical-dictionary on 22-03-2011).

13. Fat mass

Body fat is a lipid produced in the body, and this may be influenced by diet, exercise and genetics. Body fat percentage is that percentage of body mass that is not made up of bone, muscle, connective tissue and fluids; that is, everything else.

14. Bone mass

The mineral content of bone is generally referred as bone mass. The amount of bone tissue present in the body at full maturation of the skeleton is the peak bone mass.

15. Bone mineral content

The amount of mineral per square centimeter of bone is referred as bone mineral content in clinical practice (medconditions on 22-03-2011).
16. BMD

Bone mineral density is a medical term referring to the amount of matter per square centimeter of bones. BMD is used in clinical medicine as an indirect indicator of osteoporosis and fracture risk (Wikipedia, 2010). It is a measure of bone density, reflecting the strength of bones as represented by calcium content.

17. Bone remodeling

Bone remodeling is absorption of bone tissue and simultaneous deposition of new bone; in normal bone the two processes are in dynamic equilibrium. The continuous turnover of bone matrix and mineral that involves first, an increase in resorption and later, reactive bone formation is called bone remodeling (Marieb, 2000).

18. DEXA

Dual Energy X-ray Absorptiometry is a means of measuring BMD. Two X-ray beams with differing energy levels are aimed at the patient's bones. When soft tissue absorption is subtracted out, the BMD can be determined from the absorption of each beam by bone (Wikipedia, 2010).

19. Muscular performance

In the context of this study, muscular performance refers to ability of the muscle to act against resistance during different situations. It is the ability of an athlete to exhibit static strength, dynamic strength, muscle endurance and explosive strength.

20. Static strength

It is the ability of the muscle to exert force while it is neither extended nor contracted. It is the force or torque of reaction achieved when a maximum effort is
exerted by a voluntary static action of a muscle for 2-6 seconds (sportsmedicinedictionary on 28-03-2011).

**21. Dynamic strength**

The ability of an individual to exert muscular force repeatedly or over a period of time. It is especially concerned with forces which produce or change the motion of a mechanical system.

**22. Muscular endurance**

Muscular endurance is the ability of a muscle or group of muscles to sustain repeated contractions against a resistance for an extended period of time.

**23. Explosive strength**

It is the ability of neuromuscular system to produce greatest possible impulse in a given time period, which depends on resistance of the load, and organisation of the acceleration. Muscular power is the ability to exert maximum force in minimum time. It is the rate at which one can perform work.

**24. Hand grip strength**

Grip strength is the force applied by the hand to pull on or suspend from objects and is a specific part of hand strength.

**25. Chronic diseases**

A chronic disease is a disease that gets progressively worse over time and can last from months to years. It is a sort of disease that persists over a long period. The symptoms of chronic disease are sometimes less severe than those of the acute phase of the same disease. Chronic disease may be progressive, result in complete or partial disability, or even lead to death (Medical- dictionary on 28-03-2011).
26. Osteoporosis

Osteoporosis is a condition characterized by a decrease in the density of bone, decreasing its strength and resulting in fragile bones (medicinenet on 28-03-2011). It is the thinning of bone tissue and loss of bone density over time.

THE SIGNIFICANCE OF STUDY

Possessing higher BMD during each stage of life starting from childhood through old age is a key to wellbeing of any individual. Moderate to high BMD especially at old age will reduce the risk of fall and thereby decrease the incidence of fractures. The process of bone mass acquisition starts from young age and completes during middle age of life. This bone mass is maintained throughout life span, although diet, sex and lifestyle are equally crucial. Keeping health and wellbeing as the main concern, this investigation is designed to assess the levels of BMD in adolescence involved in different loading patterns and age matched no loading group. The findings of this study will have the following significant contributions.

1. The results of the study will reveal the effectiveness of loading patterns for acquiring high BMD at the age of 15 to 19 years.

2. The study reveals site specific and total body BMD status of boys and girls which can be compared with their counterparts having dissimilar characteristics.

3. The results of the study will determine the association between muscle performance and BMD.

4. The study upholds the importance of studying bone health in Indian conditions and creates avenues for future research.
5. The findings of the study inculcate awareness on the need for acquiring high BMD and thereby attain wellbeing.

6. The study helps in reporting the scores of BMD in terms of t-scores and other normative data for making interpretations.

7. The study explores the importance of physical exercise over sedentary life style in high BMD acquisition.