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(REVIEW ARTICLE)

The effect of moderate intensity exercise on increasing bone density

Anis Irmawati [1,*], Awalia Aprilizahrani Patiran [2], Aqsa Sjuhada Oki [1], Sidarningsih [1], Retno Indrawati R [1], Indeswati Diyatri [1], Noeroel Widajati [3], Noor Faizah Balqis [4], Fitriatuz Zakia [2], Nadia Rahma Adriyanti [5], Shafa Naila Maharani Madjid [5], Raed Labib [6] and Abdulkarem Ali Ali Muhammed [7]

[1] *Oral Biology Department, Faculty of Dental Medicine, Airlangga University, Surabaya, Indonesia.*
[2] *Post graduate Student, Faculty of Dental Medicine, Airlangga University, Surabaya, Indonesia.*
[3] *Department of Occupational Safety and Health, Faculty of Public Health, Airlangga University, Surabaya, Indonesia.*
[4] *Post graduate Student, Faculty of Public Health, Airlangga University, Surabaya, Indonesia.*
[5] *Under graduate Student, Faculty of Dental Medicine, Airlangga University, Surabaya, Indonesia.*
[6] *Postgraduate Program of Dental Medicine, Faculty of Dental Medicine, Airlangga University, Surabaya, Indonesia.*
[7] *Oral Medicine and Periodontology Departement, Thamar (Dhamar) University, Yemen.*

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Abstract

Background: Bone is one of body hard tissue, consist of basic matrix substances and mineral salts which are dynamic due to the process of resorptions and remodeling as a form of metabolism. As a result of this process, maintaining bone density becomes important because it is closely related to bone strength. Exercise is a physical stressor that can affect bone composition, especially bone density if done with a certain intensity and frequency. High physical activity places a mechanical load on muscles and bones which can trigger an osteogenic stimulus. Moderate intensity exercise is an exercise with 10-20 minutes duration and can increase heart rate until 60-79% during and after exercise. It's an intensity that is safe for everyone to do and can trigger bone remodeling activities.

Objective: To evaluate the results of research regarding the effect of moderate intensity exercise on increasing bone mass density.

Discussion: When a person does moderate intensity exercise, there will be activation of mechanoreceptors in the bones as a result of increased muscle contraction activity. It will inhibit osteocyte apoptosis and increase osteoblast production. In addition, ATP production from muscles during exercise can trigger the mineralization process of osteoblasts. The osteogenic effect that exercise has on bone density is influenced by various other factors, such as genetics, gender, physical activity habits, and nutritional intake.

Conclusion: There is an increase in bone mass density after moderate intensity exercise.

Keywords: Moderate intensity exercise; Bone; Bone mass density; Good health and well being

1. Introduction

In humans, bones are the main organs in the structure of the body that have the ability to grow and develop. Its functions include protecting the organs in the body, forming body posture, and playing a role in the distribution and storage of calcium and minerals. Good and strong bones require sufficient density so that they can avoid the risk of bone health problems.[1] Bone is a complex tissue consisting of cells and matrix. This bone matrix is formed by fibers and basic substances that contain important mineral salts. Bone mass and thickness always experience dynamics of addition and

* Corresponding author: Anis Irmawati

reduction through a process called remodeling. Because of this process, maintaining bone density becomes very important. Bone density has a significant impact on bone strength. Therefore, care and efforts to maintain bone density are important in maintaining bone health and preventing bone problems such as osteoporosis. [2] Data from the Indonesian Ministry of Health reveals that the osteoporosis rate in Indonesia reaches 19.7% of the population. According to this data, 1 in 3 women and 1 in 5 men experience osteoporosis or brittle bones. The prevalence of osteoporosis in Indonesia for women aged less than 70 years is 18-30%, 50-59 years old reaches 24%. In men aged between 60 and 70 years the osteoporosis rate can reach 62%.[39]

Bone density can be influenced by the habit of doing physical activities that support body weight. High physical activity or use of body weight as support can influence the osteogenic stimulus. This phenomenon is closely related to increased bone density. In addition, physical activity also has a function as a mechanical load which plays a role in stimulating bone formation thereby influencing the size, shape and strength of bones.[3] From this explanation, it can be said that physical activity and exercise can play a role in increasing bone density. High bone density and mass are expected to be achieved at peak bone mass so that when the process of decreasing bone remodeling occurs it will take a long time to reach the point of low bone density which is at risk of osteoporosis.[2]

Prevention and early detection are quite important indicators in maintaining bone mass. There are several factors that cannot be modified, such as age and gender, which can be a source of decreased bone mass. Prevention efforts that can be taken are adequate nutritional intake such as calcium and vitamin D and exercise.[4] Muscles and bones will become bigger and stronger due to the growth process, exercise and adequate intake of certain nutrients that support bone health such as vitamin D and calcium.[5] Apart from that, efforts can be made to reduce the prevalence rate of osteoporosis by providing education to the public regarding the importance of maintaining bone health, especially in the growing age group and the elderly, to encourage moderate intensity physical activity (exercise). Preventive efforts with moderate intensity exercise are expected to reduce the incidence of osteoporosis, which if done by young people can prevent osteoporosis and if done by people in old age who have experienced a decrease in bone density can prevent its severity.[4] Based on data from the Ministry of Youth and Sports (KEMENPORA) for 2022, the sports habits of Indonesian people are at 30.93%, while in 2021 they will be at 32.80%, which shows that there is a decline in the level of participation or habits of Indonesian people for sports.

Exercise is a physical stressor that can affect bone composition. Sport is a repetitive physical activity that aims to maintain, improve and express fitness.[2] Based on the duration and intensity of exercise, exercise is grouped into 3 types, namely exercise *endurance,* strength sports and sports power.[6] Heart rate and Maximum Work Capacity (KKM) can be parameters of a person's exercise intensity. Exercise is categorized as heavy intensity when *heart rate* when and after exercise reaches 80-90% of *maximal heart rate* with an activity duration of 20-30 minutes, moderate intensity 60-79% with an activity duration of 10-20 minutes, and low intensity <60% with an activity duration of less than 10 minutes.[7]

There are many benefits that can be obtained from exercise, namely improving health and preventing the emergence of various diseases such as type 2 diabetes, heart disease, osteoporosis, forms of cancer, obesity and injury. Apart from that, exercise is also known to reduce depression, stress, anxiety, increase self-confidence, increase energy, improve sleep quality and affect the ability to concentrate.[8]

Calcium and vitamin D are related to metabolic processes in the body. Low calcium intake causes a decrease in calcium levels in the blood which then triggers the secretion of parathyroid hormone, resulting in increased bone resorption which is a risk factor for decreased bone density. As we age, the level of calcium absorption in the human body decreases, thereby reducing blood calcium levels, causing secondary hyperparathyroidism and increasing bone resorption, causing osteoporosis.[9]

When a person experiences a decrease in bone quality, the bones that are generally affected include the spine, groin, wrist and various parts of the jawbone (including the condyle neck in 29%, the angle of the mandible in 24% and the symphysis in 22%). This decrease in bone quality is mostly caused by osteoporosis. [10]

Based on the description above, the author wants to analyze the effect of exercise, especially moderate intensity, on increasing bone density, especially the jawbone. Moderate intensity was chosen as the topic because moderate intensity exercise can have a good effect on the body if done with a certain frequency, and can be done by everyone. Low intensity exercise can have less significant effects on the body, especially on bone density. Meanwhile, high intensity exercise cannot be done by everyone and has a high risk of injury.

2. Literature Review Material and methods

2.1. Bone

Bones are part of the body of living creatures, both animals and humans, which is a tissue with the highest level of hardness compared to other body tissues. Bones are formed from minerals, 76% of which is calcium phosphate, and 33% is other cellular material. Even though most bone components are minerals, bones still have a vascular structure and cellular activity that is closely related to their function. Bones generally have a function as forming and supporting the body, protecting internal organs (visceral), means of locomotion, place for attachment of muscles, place for formation of blood cells, storage of calcium ions, and plays a role in calcium homeostasis in the blood.[11–13]

Osteoclasts, osteoblasts and other bone-forming cells are cellular components found in bones and play an important role in bone metabolism and growth processes. These include regulating the level of density, speed of bone formation, thickness of the cortical layer, and the formation of lamella structures in bones.[14]

Based on their shape, bones can be classified into[14]: a) Long bones, namely bones whose length exceeds their width, such as the humerus, radius, femur, tibia, metacarpal and metatarsal; b) Short bones, anatomically shaped like short cubes, such as the carpal and tarsal bones; c) Flat bones, flat and flat, found in the sternum, ribs, scapula, as well as several bones that make up the skull; Irregular bones, anatomically do not have a clear shape, are found in the vertebrae and several bones that make up the face; e) Sesamoid bones, are small bones that are attached to tendons, like bones patella as well as the bones found on the proximal and distal sides of the fingers.

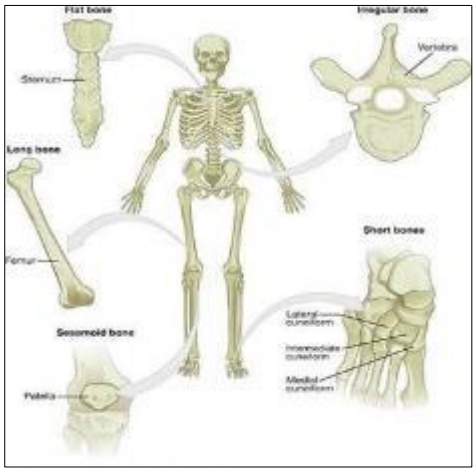

Figure 1 Types of bones based on their shape [14]

Apart from shape, bones can also be classified based on density [12], includes: a) Hard bones, namely bones whose matrix is densely composed of organic base materials and inorganic salts, leaving little space (lacunae) which contains osteocytes or bone cells. Hard bones make up 80% of human skeletal structure and play an important role in supporting and strengthening the body[11]; b) Trabecular bone, is bone that has a softer and porous consistency than hard bone, has a structure like sponge or honeycomb filled with bone marrow or blood vessels. Trabecular bones make up 20% of human skeletal structure, and function for support and flexibility. So, these bones are found more often in areas of the body that are not subject to large mechanical stress[12]; c) Cartilage or cartilage, is a bone that is often found during the growth period, where most of this bone will later develop into hard bone. Cartilage is hard, but elastic. Formed from chondrocyte cells which secrete matrix material and collagen fibers.[11]

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2.1.1. Bone Metabolism

Bone is a hard tissue in the body that actively undergoes metabolic processes to maintain homeostasis of the minerals and cells that make it up. The bone metabolic process is a dynamic process that involves processes remodeling and

resorption which occurs simultaneously. This process aims to maintain the mass, structure and quality of the body's skeleton through balancing resorption activity by osteoclast cells and remodeling by osteoblast cells.[15]

Bones, as the body's supporting tissue, will experience microdamage at any time. This can occur due to the release of ions, minerals or calcium by chemotactic factors from the body.[16] This release process attracts osteoclast precursors to move to the area experiencing microdamage, and triggers the activation of RANK as a surface receptor on bone cells to be activated and bind to its ligand, namely RANKL. This RANK-RANKL bond triggers the activation and differentiation of osteoclast precursors into mature osteoclasts. Mature osteoclasts will then attach to the surface of the bone, forming actin ring/sealing zone on the bone surface to secrete hydrochloric acid and proteolytic enzymes so that the bone matrix will be damaged.

Mature osteoblasts that have formed will attach to the area of bone matrix undergoing resorption, and carry out calcification by secreting type I collagen-rich osteoid matrix as well as remineralization of the area. During this process, osteoblasts in the matrix will differentiate into new osteocytes[15,17]

2.1.2. Bone Density

Bone is a hard tissue composed of an organic matrix in the form of type I collagen and a mineral matrix in the form of hydroxyapatite crystals which are bound to collagen fibers. The components that make up the matrix provide mechanical characteristics, where collagen and hydroxyapatite crystals provide strong properties and are resistant to plastic deformation. Any change in matrix composition, increase or decrease in matrix density, either physiologically or pathologically will affect the mechanical properties of bone. An increase in the amount of collagen is closely related to the level of bone plasticity.[18]

The quantity of trabecular bone and cortical bone composition influences bone density and strength. This is closely related to the level of bone remodeling and resorption. After a person's growth period is complete and the bones have matured, the level of external activity and hormonal changes will be factors that influence the rate of bone remodeling and resorption. Bone mineral density (BMD) or bone density is a method of measuring the composition of inorganic minerals in bones and a method of clinically evaluating bone quality. BMD is defined as the comparison or ratio of bone mass to bone size in grams per centimeter. This method is used to find out how strong or weak a person's bones are (bone density), so that it can be seen whether a person has osteoporosis, osteopenia, or is at risk of fracture.

Maximum bone density shows the maximum amount of bone density throughout the body achieved by a person, where this condition can be reached up to 90% at the age of 18 years. Most of the women are in the age range of 13-17 years post menarche, while in men aged 18-20 years.[19]

Bone density or bone mineral density is another parameter for measuring bone health *bone mineral content* (BMC). A person's bone density will certainly not be constant from growth to adulthood, because there are many influencing factors. Some of these factors include:

Gender

Study conducted by Segheto regarding factors that influence BMD in adults, states that there are differences in BMD values for men and women. In men, the physiological decline in bone density due to age lasts longer, because men have a BMD value that is 25% higher than women.[20]

Hormones

Several types of hormones influence bone density levels, such as estrogen, testosterone, androgens, growth hormones, insulin like growth factor-1 (IGF-1) which plays a role in the process remodeling and bone formation. Growth Hormone (GH) is a polypeptide hormone secreted by somatotroph cells from the anterior pituitary gland. When GH is in the blood circulation, it will bind and activate receptors on the surface of cells in the liver, bones, muscles and adipose tissue. This interaction induces IGF-1 production. GH plays a major role in postnatal longitudinal growth through induction of bone growth and regulation of lipid, carbohydrate, mineral metabolism and mineral homeostasis. Impaired GH production during growth manifests as gigantism, acromegaly and GH deficiency syndrome in adults. [21,22]

IGF-1, which is produced by osteoblast cells, functions for the proliferation of basal cells and chondrocytes in bones. Meanwhile, IGF-1, which is produced by the liver and circulates systemically, functions to activate the bone remodeling process and anabolic metabolism in bone tissue when there is physical activity.[23] Physiologically, IGF-1 levels will decrease with age along with decreased GH secretion and endocrine gland function. In women, IGF-1 levels will decrease

drastically after menopause, due to the influence of the hormone estrogen which works synergistically on bone metabolism, so that menopause is usually accompanied by a decrease in bone density and an increased risk of osteoporosis[10,22]

Besides GH, sex hormones (androgens, estrogen, testosterone) also participate in bone metabolism. Androgens are needed to mediate growth in the periosteal area of bone in both women and men. However, men have higher androgen levels than women, so men have a thicker cortical layer and bone density levels are generally at a higher level than women. Androgens also play a role in stimulating osteoblast precursors in the process remodeling by inducing the secretion of interleukin-1β (IL-1b), suppressing osteoblast apoptosis and triggering osteoclast apoptosis together with estrogen. Meanwhile, estrogen plays a role in maintaining the thickness of the cortical layer and cancellous areas in the bone by increasing the production of osteoprotegerin and inhibiting it signaling pathway bone resorption cytokines, such as IL-1, IL-6, tumor necrosis factor a (TNF-α).

Testosterone is mostly produced by Leydig cells as a result of stimulation from gonadotropin-releasing hormone (GnRH) which is secreted by the hypothalamus and Luteinizing Hormone (LH) from the anterior pituitary gland. Testosterone works by activating receptor proteins in bones, especially in the trabecular area of bone to increase calcium absorption activity and increase osteoblast activity together with estrogen. Apart from that, testosterone also plays a role in the expansion of the periosteal area of the bone.[24]

In general, sex hormones in bone metabolism play an important role in the remodeling and resorption processes. Therefore, women experience increased bone resorption after experiencing menopause at around 50 years of age, due to decreased production of the hormone estrogen. Meanwhile, in men, this condition occurs more slowly, namely at the age of 70 years, where testosterone production will decrease.[20]

Apart from GH and sex hormones, glucocorticoid and adrenocorticotropic hormone (ACTH) also play a role in bone metabolism, but with the opposite mechanism. Glucocorticoid affects bone metabolism by inhibiting the osteogenic process and the expression of osteogenic proteins such as alkaline phosphatase and osteocalcin, resulting in barriers to maturation, disruption of function, and reduced lifespan of osteoblast cells. According to Cannarella based on related studies *glucocorticoid-induced osteoporosis*, that glucocorticoids can trigger osteoblast apoptosis and inhibit hydration and blood flow to the bones so that the bones will experience osteonecrosis. Apart from inhibiting osteoblast cells, glucocorticoid can also induce secretion cathepsin K which functions to remove type I collagen and other proteins in the bone matrix which triggers a decrease in bone density.[25]

In contrast, ACTH works by triggering the differentiation of osteoblast cells by increasing the expression of bone-specific genes such as type I collagen genes, vitamin D receptors, and TGF-β.[25] Calcitonin is also a hormone that plays an important role in bone metabolism, especially in relation to calcium absorption and regulation of calcium levels in the body's circulation. Calcitonin is a peptide hormone secreted from the parafollicular cells of the thyroid gland. According to a study conducted by Xie, states that calcitonin works directly in inhibiting bone resorption and collagen breakdown by increasing the absorption of calcium and vitamin D in bone cells.[26] Apart from calcitonin, calcitriol or a hormone produced by enzymes in the liver and kidneys from vitamin D is in the form of 1.25 dihydroxy vitamin D plays a role in increasing the absorption of calcium and phosphate in the digestive system for bone mineralization. Calcitriol also induces production calcium-binding protein such as osteocalcin and osteopontin in osteoblasts. This hormone can also trigger osteoclast maturation indirectly when it binds to RANKL which will activate the bond with RANK and trigger the differentiation of preosteoclasts into mature osteoclasts. Calcitriol in the digestive system works to influence bone metabolism through the activation of specific receptors in the digestive system which will increase the digestive mucosa's absorption of calcium and phosphorus. Calcitriol, which is in the kidneys, works by influencing calcium transport in the distal tubule by increasing the action of parathyroid hormone, so that there will be an increase in phosphate absorption in the kidneys.[26]

Consumption of cigarettes and alcohol

Through the same study by Segheto, results also showed that smokers had lower BMD values than non-smokers, although the difference in results did not show a significant number. Some literature states that nicotine consumption will directly interfere with the absorption of vitamin D by the bones and interfere with the work of parathyroid hormone which has an effect on bone health. Apart from cigarettes, alcohol consumption also has the same effect, namely inhibiting the absorption of vitamin D and disrupting the work of parathyroid hormone, androgen and estrogen which are directly related to bone metabolism.[20]

Ras

Based on Segheto's research object, non-Caucasian research objects have higher BMD values than Caucasian research objects.[20] This shows that there is a correlation between race or skin color and BMD, which is related to the level of vitamin D absorption and bone metabolic activity. High skin pigmentation can affect the production of calciferol, which is a precursor to the 25(OH)D receptor. This receptor functions for absorption of vitamin D and activation of bone metabolism. From this study it was found that the 25(OH)D receptor level in Caucasians was 20% lower than non-Caucasians, which is in line with the BMD results where non-Caucasians had higher BMD levels than Caucasians.[27]

Digestive microbiota

The microbiota found in the digestive system can also influence the level of bone density, where microbes play a role in fermenting fiber from the food consumed into short chain fatty acids. This fermented product can help increase calcium absorption. In addition, microbes in the digestive system can secrete incretins and serotonin, which are hormones and factors that play a role in the regulation of bone resorption and remodeling.[27]

2.2. Exercise

In general, exercise or physical activity can be categorized into 4 basic categories, including [28]:

2.2.1. Endurance

Physical activity in the endurance category can also be referred to as aerobic physical activity, where this activity increases the intensity of breathing and heart rate, such as walking, light jogging, dancing, and running. The aim of this physical activity is to improve the quality of the cardiovascular and pulmonary systems in general.

2.2.2. Strength

Physical activity that focuses on regular strength aims to improve muscle quality, with types of exercise such as weight lifting or sports activities gym form stretching with a certain amount of style.

2.2.3. Balance

Physical activity that focuses on balance aims to increase body strength, especially the lower body, which will have an impact on improving body balance. Among them include Tai Chi sports, Heel-to- toe walk, as well as ballet dancing.

2.2.4. Flexibility

Physical activity that focuses on flexibility aims to increase muscle stretchability so that the body has the ability to move more widely. These include yoga and exercise stretching simple.

Apart from these 4 basic categories, exercise can also be categorized based on the effects it has on the body, including [29]

a. Aerobic exercise, which is a category for sports or physical activities that involve the use of many muscle groups so that the oxygen consumption required is also large. The goal of aerobic exercise is to increase the endurance of the cardiovascular system. These include cycling, walking, swimming, jumping rope, climbing, and ball sports such as tennis or badminton. The use of oxygen in aerobic exercise will produce Reactive Oxygen Species (ROS) or what are commonly referred to as free radicals as a form of metabolite. ROS are reactive molecules that play a role in activating the immune system or triggering inflammation. However, ROS can only increase to a level that can trigger inflammatory processes during vigorous intensity aerobic exercise. Moderate intensity exercise will not trigger excess ROS production.[30]

b. Anaerobic exercise is a category for sports or physical activities that require muscle strength and endurance. The aim of this sport is to improve muscle, bone strength, balance and body coordination. These include push-up, weight lifting, weight training, interval training, sprinting.

Another division of sports is based on the intensity performed. Intensity in exercise can be measured through changes in heart rate individuals after and during exercise,[28,29] including:

a. Light intensity exercise, which does not cause significant changes in heart rate rhythm. When someone does light exercise, there tends to be no sweat production and changes in breathing patterns that occur. According to Maulana,

when someone does light intensity exercise, there will be a change in heart rate of <60% maximal heart rate. These include walking and typing activities.[7]

b. Moderate intensity exercise, which causes changes in the rhythm of the heartbeat and causes sweat production in a person if done for at least 10 to 20 minutes. When someone does moderate intensity exercise, there will be a change in the breathing pattern which becomes deeper and the breathing frequency and changes increase heart rate amounting to 60-79% of maximal heart rate.[7] Cycling is an example of moderate intensity exercise.

c. Heavy intensity exercise, which is characterized by breathing patterns that become heavy, frequency, and heart rate increases significantly after doing it for just 3-5 minutes. Examples include running, jogging, push up, sit up, jumping jacks, to jump rope.

2.2.5. Benefits of Exercise for Health

Exercise is physical activity that triggers most of the organs in the body to be active, including triggering hormones to function to maintain body homeostasis during the process of physical activity. According to Elmagd, sport or physical exercise that is done regularly has several benefits, including[28]:

a. Improving the quality of work of the cardiovascular system, where the heart's ability to pump blood will increase and the lung capacity to take in oxygen will also increase.

b. Reducing the risk of heart attack, stroke or other heart disorders because regular exercise can make the heart work more efficiently, blood vessels are more elastic and flexible so that blood flow and pressure will tend to be at normal levels. According to American Heart Association (AHA), heart health will improve significantly if someone exercises regularly for 30 minutes per day.

c. Reduce stress and anxiety. Several studies state that physical exercise triggers release norepinephrine and related endorphins stress relief on the brain. Doing regular physical exercise also improves sleep quality, which will affect the general condition of the body.

d. Improve brain abilities. Several studies state that physical activity can form new cells in the brain (neurogenesis) as well brain-derived protein (BDNF) which improves the quality of brain work in making decisions, thinking and receiving information.[29]

e. Increases muscle and bone strength. It is generally known that exercise has significant benefits for the musculoskeletal system because when a person exercises, muscles and bones are the organs that are actively involved. Exercise, especially strength or resistance exercise, has a significant influence on muscle mass. Both types of exercise focus on muscle activity and have quite high levels of muscle contraction. So, when doing exercise, there can be an increase in muscle mass due to increased muscle size and strength. Muscle contractions that occur with a certain intensity and duration when a person exercise will increase the number and size of muscle proteins, namely actin and myosin, as well as myofibril filaments.[31]

Muscle contractions and active pressure exerted by the body on the bones when exercising will activate mechanoreceptors in the bone periosteum, which will then trigger the activity of osteocytes and osteoblasts. So, when a person exercises, the bones will work to increase calcium resorption and improve the process remodeling through osteoblast activation. Several studies state that 30 minutes of exercise done 3-4 times per week can be a therapeutic modality for musculoskeletal disorders, such as osteoporosis and sarcopenia.[32]

f. Reduces the risk of obesity and maintains cholesterol levels. Sport or physical activity is an activity that also aims to burn calories in the body, where the higher the intensity of the activity, the more calories are burned. Several studies state that moderate intensity cardio physical activity carried out regularly 5-7 days a week can reduce body weight effectively.[28,29]

3. Discussion

Bone quality is determined by several factors, starting from each individual's bone morphology, nutrition, and the intensity of physical activity carried out every day. Sport is a form of physical activity recommended by American College Sports of Medicine (ACSM) as a non-pharmacological method for maintaining bone mass, especially moderate

to heavy intensity exercise. According to Maulana, moderate intensity exercise, is exercise that lasts 10-20 minutes and can cause changes *heart rate* amounting to 60-79% of heart rate maximum.[7]

Research conducted by Rungkat on 25 young adult female students who play sports *step up* for 6 weeks with a frequency of 3 times per week lasting 20 minutes per session, states that there is an increase in bone density before and after exercise *step up*.[4] These results show that exercise *step up* moderate intensity can affect bone mass in young adult women. This is in line with research conducted by Cheng also showed an increase in bone density in adult women aged 45-55 years who did exercise Tai Chi and brisk walking for 48 weeks. In this study, bone density increased significantly after exercise, especially in the femur and spine.[33]

Apart from that, the effect of moderate intensity exercise on bone density can also be seen from increasing serum levels of calcium or calcitonin in the blood. Research conducted by Alghadir on adult individuals (30-59 years) who did aerobic exercise for 12 weeks with a frequency of 3 times per week for 10-20 minutes, showed that there was an increase in serum calcium or calcitonin levels in the bones after doing this exercise for 12 weeks.[3] An increase in serum calcium indicates an increase in bone density in individuals after exercise. Similar research conducted by Kaushik on adult women (20-50 years) who carried out physical activity walking for 30 minutes per day also showed that there was an increase in serum calcium levels in the blood 24 hours after exercise.[34] This research also shows that moderate intensity exercise causes changes in several biological parameters in the body, including blood sugar, electrolytes and serum calcium in the blood, where there is a decrease to normal levels one hour after exercise, then an increase 24 hours after exercise when metabolism the body returns to normal condition.

Research from Senduk on young adults who did Zumba exercise lasting 10-45 minutes for 4 weeks with a frequency of 3 times per week, showed that there was no significant difference in bone mass before and after doing Zumba exercise.[35] In this study, it was found that in 3 respondents and 13 other respondents there was no change in bone mass. However, from the results of this study it can also be seen that there is no decrease in bone mass after Zumba exercise, which shows that Zumba exercise can suppress the process of bone resorption. Research conducted by Chastin also stated that there was an increase in bone mass in women after carrying out physical activity of walking for 10-20 minutes every day for one week.[36] Increased bone mass occurs especially in the femur. However, there was no bone increase in male subjects who did physical activity with the same intensity. These results indicate that there are other factors that influence increasing bone density apart from physical activity, one of which is gender.

Research conducted by Bolam and Hinton with subjects in adult men who did moderate intensity exercise in the form of jump exercise with a duration of 20-30 minutes or 40 jumps per session shows that there is no significant increase in bone mass after this exercise.[37,38] However, on the subject who did jump exercise heavy intensity (80 jumps per session) in Bolam's research found a significant increase in bone mass, especially in the hip and thigh bones.[37] This shows that in men, a more significant increase in bone density occurs when doing heavy intensity exercise. This statement is supported by Chahal through his research on adult individuals who frequently exercised and were asked to exercise gradually from moderate intensity such as walking to vigorous intensity for 10 hours. The results showed that there were changes in the level of muscle strength and changes in bone density when someone did exercise, but these changes were at different levels according to the intensity.[32]

These various studies show that when a person does moderate intensity exercise, there will be activation of mechanoreceptors in the bones as a result of increased muscle contraction activity. Activation of these mechanoreceptors will trigger an osteogenic process, in the form of inhibiting osteocyte apoptosis and increasing osteoblast production. In addition, ATP production from muscles during exercise can cause receptor activation in osteoblasts and osteocytes which will trigger the mineralization process of osteoblasts. In addition, when a person exercises, there will be an increase in hypothalamus activity which causes an increase in the production of anabolic hormone metabolism as well growth factor. This hormone is a hormone that plays a role in mineral homeostasis in the processes of bone resorption and remodeling, as well as increasing the absorption of calcium from the diet. Growth hormone will be induced in high amounts when muscle and bone cells are in an active condition during exercise. Likewise, FSH and LH induce sex hormones It will also increase when someone does physical activity. Induction sex hormones can cause an increase in the bone mineralization process through increasing the activity of intracellular calcium ions in L-type voltage calcium channel gate in osteoblast cells that are sensitive to mechanical stimulation.[3,33]

The osteogenic effect that exercise has on bone density is influenced by various other factors, such as genetics, gender, physical activity habits, and nutritional intake. In women, exercise can provide significant results in increasing bone density if done with moderate intensity but regularly compared to doing vigorous exercise but not doing it regularly. Meanwhile, in men, light to moderate intensity exercise is less likely to provide significant results on bone density. Significant increases in bone density can be seen with vigorous intensity exercise. This difference in effect may occur

because men tend to do physical activity with higher intensity more often than women. This causes the metabolic response, muscle strength and bones between men and women to also be different.[32]

4. Conclusion

Increasing bone mass density can be seen after doing moderate intensity exercise. The location of a significant increase in bone density depends on which bone that affected by the exercise. However, other factors that affect bone density beside exercise are genetics, gender, physical activity habits, and nutritional intake. Thus, moderate intensity exercise could promote healthy lives and well-being for all at all ages.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Bella AK, Polii H, Wungow HIS. Pengaruh Latihan Resisten terhadap Kepadatan Tulang. Jurnal E-Biomedik 2021;9. https://doi.org/10.35790/ebm.v9i2.31799.

[2] Lesmana HS, Broto EP. OLAHRAGA SEBAGAI UPAYA PREVENTIF OSTEOPOROSIS DINI. n.d.

[3] Alghadir AH, Aly FA, Gabr SA. Effect of moderate aerobic training on bone metabolism indices among adult humans. Pak J Med Sci 2014;30. https://doi.org/10.12669/pjms.304.4624.

[4] Rungkat TA, Lintong F, Moningka MEW. Pengaruh Olahraga Step Up terhadap Massa Tulang pada Wanita Dewasa Muda. Jurnal Biomedik 2020;12:54–60. https://doi.org/10.35790/jbm.12.1.2020.27092.

[5] Isaacson J, Brotto M. Physiology of mechanotransduction: How do muscle and bone "talk" to one another? Clin Rev Bone Miner Metab 2014;12:77–85. https://doi.org/10.1007/s12018-013-9152-3.

[6] Muth ND. Sports Nutrition for Health Professionals. 2015.

[7] Arya Maulana S, Touvan Y, Samodra J, Firsta Yosika G, Gandasari F, Dwi I, et al. Dampak Aktivitas Fisik (Jogging) terhadap Denyut Nadi Latihan. 2023.

[8] Juniarto M, Subandi OU, Sujarwo S. Edukasi Olahraga Dalam Upaya Meningkatkan Kebugaran dan Kesehatan Masyarakat Kota Bekasi Provinsi Jawa Barat. Dharma Raflesia : Jurnal Ilmiah Pengembangan Dan Penerapan IPTEKS 2022;20:16–23. https://doi.org/10.33369/dr.v20i1.18759.

[9] Amato A, Baldassano S, Cortis C, Cooper J, Proia P. Physical activity, nutrition, and bone health. Human Movement 2018;19:1–10. https://doi.org/10.5114/hm.2018.77318.

[10] Barake M, Arabi A, Nakhoul N, El-Hajj Fuleihan G, El Ghandour S, Klibanski A, et al. Effects of growth hormone therapy on bone density and fracture risk in age-related osteoporosis in the absence of growth hormone deficiency: a systematic review and meta-analysis. Endocrine 2018;59:39–49. https://doi.org/10.1007/s12020-017-1440-0.

[11] Lin CY, Kang JH. Mechanical properties of compact bone defined by the stress-strain curve measured using uniaxial tensile test: A concise review and practical guide. Materials 2021;14. https://doi.org/10.3390/ma14154224.

[12] Osterhoff G, Morgan EF, Shefelbine SJ, Karim L, McNamara LM, Augat P. Bone mechanical properties and changes with osteoporosis. Injury 2016;47:S11–20. https://doi.org/10.1016/S0020-1383(16)47003-8.

[13] Lucas D. Structural organization of the bone marrow and its role in hematopoiesis. Curr Opin Hematol 2021;28:36–42. https://doi.org/10.1097/MOH.0000000000000621.

[14] Setiawati R, Rahardjo P. Bone Development and Growth. Osteogenesis and Bone Regeneration, IntechOpen; 2019. https://doi.org/10.5772/intechopen.82452.

[15] Kenkre JS, Bassett JHD. The bone remodelling cycle. Ann Clin Biochem 2018;55:308–27. https://doi.org/10.1177/0004563218759371.

[16] Wawrzyniak A, Balawender K. Structural and Metabolic Changes in Bone. Animals 2022;12. https://doi.org/10.3390/ani12151946.

[17] Ralston SH. Bone structure and metabolism. Medicine (United Kingdom) 2017;45:560–4. https://doi.org/10.1016/j.mpmed.2017.06.008.

[18] Diomede F, Marconi GD, Fonticoli L, Pizzicanella J, Merciaro I, Bramanti P, et al. Functional relationship between osteogenesis and angiogenesis in tissue regeneration. Int J Mol Sci 2020;21. https://doi.org/10.3390/ijms21093242.

[19] Kranioti EF, Bonicelli A, García-Donas JG. Bone-mineral density: clinical significance, methods of quantification and forensic applications. Research and Reports in Forensic Medical Science 2019;Volume 9:9–21. https://doi.org/10.2147/rrfms.s164933.

[20] Segheto KJ, Juvanhol LL, de Carvalho CJ, da Silva DCG, Kakehasi AM, Longo GZ. Factors associated with bone mineral density in adults: A cross-sectional population-based study. Revista Da Escola de Enfermagem 2020;54. https://doi.org/10.1590/S1980-220X2018039903572.

[21] Lu M, Flanagan JU, Langley RJ, Hay MP, Perry JK. Targeting growth hormone function: strategies and therapeutic applications. Signal Transduct Target Ther 2019;4. https://doi.org/10.1038/s41392-019-0036-y.

[22] Wydra A, Czajka-Oraniec I, Wydra J, Zgliczyński W. The influence of growth hormone deficiency on bone health and metabolism. Reumatologia 2023;61:239–47. https://doi.org/10.5114/reum/170244.

[23] Varlamov E, McCartney S, Fleseriu M. Growth hormone deficiency and replacement effect on adult bone mass: A clinical update. Curr Opin Endocr Metab Res 2018;3:7–20. https://doi.org/10.1016/j.coemr.2017.10.001.

[24] Narla RR, Ott SM. Bones and the sex hormones. Kidney Int 2018;94:239–42. https://doi.org/10.1016/j.kint.2018.03.021.

[25] Cannarella R, Barbagallo F, Condorelli RA, Aversa A, La Vignera S, Calogero AE. Osteoporosis from an endocrine perspective: The role of hormonal changes in the elderly. J Clin Med 2019;8. https://doi.org/10.3390/jcm8101564.

[26] Liao RX, Yu M, Jiang Y, Xia W. Management of osteoporosis with calcitriol in elderly Chinese patients: A systematic review. Clin Interv Aging 2014;9:515–26. https://doi.org/10.2147/CIA.S40465.

[27] Redondo-Cuevas L, Sanchis-Chordà J, Codoñer-Franch P. Child nutrition and bone health. Journal of Child Science 2018;8:e67–74. https://doi.org/10.1055/s-0038-1669402.

[28] Elmagd MA. Benefits, need and importance of daily exercise. ~ 22 ~ International Journal of Physical Education, Sports and Health 2016;3:22–7.

[29] Piotrowska K, Pabianek Ł. Physical activity – classification, characteristics and health benefits. Quality in Sport 2019;5:7–14. https://doi.org/10.12775/qs.2019.007.

[30] Nunes Silva A. The Association between Physical Exercise and Reactive Oxygen Species (ROS) Production. J Sports Med Doping Stud 2015;05. https://doi.org/10.4172/2161-0673.1000152.

[31] Tambing A, Engka JNA, Wungouw HIS. Pengaruh Intensitas Latihan Beban terhadap Massa Otot. EBiomedik 2020;8:1–10. https://doi.org/10.35790/ebm.8.1.2020.27099.

[32] Chahal J, Lee R, Luo J. Loading dose of physical activity is related to muscle strength and bone density in middle-aged women. Bone 2014;67:41–5. https://doi.org/10.1016/j.bone.2014.06.029.

[33] Miguel R, Da Costa G, Neiva CM, Costa H, He B, Com B, et al. Effects of Tai Chi and brisk walking on the bone mineral density of perimenopausal women: A randomized controlled trial. 2022.

[34] Kaushik M, Pahwa M, Verma R. ALTERATION IN ROUTINE BIOCHEMICAL PARAMETERS AFTER MODERATE PHYSICAL EXERCISE IN HEALTHY PREMENOPAUSAL FEMALE VOLUNTEERS. International Journal of Medical Reviews and Case Reports 2022:1. https://doi.org/10.5455/ijmrcr.alterationinroutinebiochemicalparameters.

[35] Senduk MNW, Polii H, Doda DVD. Perbandingan Massa Tulang Sebelum dan Sesudah Melakukan Senam Zumba pada Wanita Dewasa. 2019.

[36] Chastin SFM, Mandrichenko O, Helbostadt JL, Skelton DA. Associations between objectively-measured sedentary behaviour and physical activity with bone mineral density in adults and older adults, the NHANES study. Bone 2014;64:254–62. https://doi.org/10.1016/j.bone.2014.04.009.

[37] Bolam KA, Skinner TL, Jenkins DG, Galvao DA, Taaffe DR. The Osteogenic Effect of Impact-Loading and Resistance Exercise on Bone Mineral Density in Middle-Aged and Older Men: A Pilot Study. Gerontology 2015;62:22–32. https://doi.org/10.1159/000435837.

[38] Hinton PS, Nigh P, Thyfault J. Effectiveness of resistance training or jumping-exercise to increase bone mineral density in men with low bone mass: A 12-month randomized, clinical trial. Bone 2015;79:203–12. https://doi.org/10.1016/j.bone.2015.06.008.