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Osteoporosis

INDEPENDENT LEARNING MATERIAL FOR PHYSIOTHERAPY STUDENTS

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Abstract

Osteoporosis is a progressive metabolic disease that leads to decreased bone mineral density (BMD) and bone strength, increasing the risk of fractures. The incidence of osteoporosis and fragility fractures increase with aging. Additionally, deficiency of certain minerals, vitamins, and hormones as well as physical inactivity can predispose to bone loss. Whereas reduced muscle strength and balance, can increase the risk of falls and lead to fractures.

The objective of the thesis was to gather evidence-based information about osteoporosis – its pathophysiology, risk factors, signs and symptoms, diagnosing, as well as its prevention and treatment, and to create an independent learning material for physiotherapy students. The independent learning material will be part of Medical Sciences and Pharmacology course, in SAMK's physiotherapy degree program. It is available for students in H5P Moodle platform.

Prevention and treatment of osteoporosis consists predominantly the same strategies: healthy lifestyle habits, appropriate nutrition, adequate intake of calcium and vitamin D as well as physical activity (PA) and exercise. Physiotherapist's role is focused on PA and exercise. Mechanical loading during weight-bearing impact activity and resistance training has been shown to improve BMD and bone strength whereas muscle strengthening, and balance/agility training can reduce the risk of falls, and therefore prevent fractures.

Key words:
osteoporosis, prevention and treatment, physical activity, independent learning material

CONTENTS

1 INTRODUCTION

Osteoporosis is a metabolic bone disease that leads to decreased bone mineral density (BMD) and bone strength and can increase the risk of fractures (Bolster, 2023). It has been estimated that osteoporosis affects approximately 500 million people worldwide, and this number continues to increase due to the aging population and changes in lifestyle. Moreover, osteoporosis is a significant public health concern causing more than 8.9 million fractures every year and leading to huge economic costs. (IOF, n.d.)

Bone is alive tissue that is constantly growing, remodeling, and repairing itself. In addition to various minerals, vitamins and hormones, mechanical stress is an important factor that affects to BMD and bone strength. Athletes performing in high-impact sports, thus continuously exposing their bones under great stress, seem to have an increased overall bone mass. On the other hand, astronauts have shown to lose significant amount (up to 20%) of their bone density after spending extended periods in the weightless environment of space. (Tortora & Derrickson, 2018, p. 147, 160)

Although genetics greatly contribute to bone mass and consequently to the risk of developing osteoporosis, there are ways in which the risk of osteoporosis can be reduced. The prevention should begin already during childhood with the focus on proper nutrition and diverse physical activity (PA). Healthy lifestyle habits, and adequate intake of calcium and vitamin D, are also ways to prevent and manage osteoporosis. Additionally, osteoporosis can be treated with pharmacological therapies, and fall prevention measures should be considered among osteoporotic patients with the increased risk of falls. PA and exercise that promote bone health are important in both prevention and treatment of osteoporosis. (Bolster, 2023; Ehrman et al., 2013, p. 447; Osteoporoosi: Käypä hoito -suositus, 2020).

2 AIM AND OBJECTIVES OF THE THESIS

The aim of the thesis is to increase the knowledge of physiotherapy students regarding osteoporosis – its pathophysiology, risk factors, as well as its prevention and treatment.

The objective of the thesis was to gather evidence-based knowledge about osteoporosis and create an independent learning material for physiotherapy students. The independent learning material will be part of SAMK's Medical sciences and Pharmacology course (a course included in the physiotherapy program), available for students in H5P Moodle platform.

3 OSTEOPOROSIS

National Institute of Health (NIH) defines osteoporosis as a bone disease which develops due to decreased bone mineral density (BMD) and bone mass and is characterized by changes in the structure and strength of the bone. It can lead to reduced bone strength and increase the risk of fractures (NIH, n.d.). Bone strength encompasses both the density and the quality of the bone. Research has found that BMD accounts for 60-90% of bone strength (Amman & Rizzoli, 2003; Dhainaut et al., 2016; NIH, 2001). Other factors that influence bone strength include bone mineralization degree, collagen properties, microarchitecture, as well as whole bone geometry (Fonseca et al., 2014).

Osteoporosis can be classified as primary (idiopathic and age-related) or secondary. In primary osteoporosis there is no identifiable underlying cause behind the disease whereas secondary osteoporosis is caused by another medical condition or medication. Possible causes of secondary osteoporosis are presented in Table 1 below. Primary osteoporosis is far more common – more than 95% of osteoporosis in women and around 80% of osteoporosis in men is primary. It is most common in postmenopausal women and in older men. In primary osteoporosis conditions, such as gonadal

deficiency, decreased calcium intake, low vitamin D levels and certain medications, may increase bone loss. Idiopathic osteoporosis is diagnosed when fragility fracture or low bone mass is present in children, adolescents, premenopausal women, and men under the age of 50 with normal gonadal function and without a detectable secondary cause. (Bolster, 2023; Osteoporoosi: Käypä hoito -suositus, 2020)

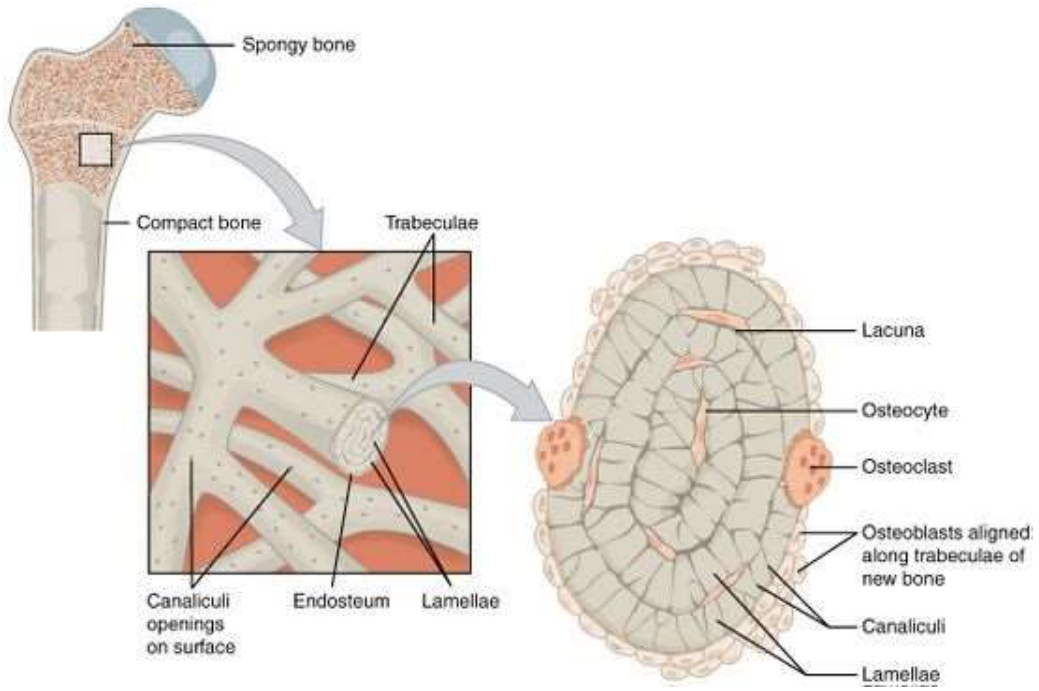
Table 1. Possible causes of secondary osteoporosis. (Adapted from Ganesan et al., 2023; Osteoporoosi: Käypä hoito -suositus, 2020)

Endocrine Problems a. Hyperthyroidism b. Hypogonadism c. Diabetes Mellitus
Chronic Inflammatory Conditions a. Rheumatoid arthritis b. Cystic fibrosis c. Chronic Obstructive pulmonary disease (COPD)
Neuromuscular Diseases a. Cerebral palsy b. Multiple Sclerosis c. Duchenne's Muscular Dystrophy (DMD)
Gastrointestinal Diseases a. Inflammatory Bowel Disease (IBD) b. Celiac disease c. Chronic liver disease
Nutritional Conditions a. Eating disorders (e.g., anorexia, bulimia) b. Bariatric surgery
Transplants a. Stem cell b. Organ: heart, lung, liver, kidney
Medications a. Glucocorticoids b. Antiepileptic drugs (phenobarbitone, phenytoin, topiramate)

3.1 Bone functions and structure

The skeletal system has various functions, for instance, it provides support and protects internal organs from injury. Additionally, one of the functions of the skeletal system is mineral homeostasis. Bone tissue stores several minerals which contribute to bone strength, such as calcium and phosphorus – 99% of the body's calcium is stored in bone tissue. On demand these minerals are released into the bloodstream to maintain homeostasis. (Tortora & Derrickson, 2018, p. 147)

There are two types of bone tissue: cancellous bone (also referred to as trabecular or spongy bone) and cortical bone (or compact bone). The skeletal system is mainly made up of cortical bone (up to 80%) and the rest is cancellous bone (about 20%). Cancellous bone has a sponge-like structure, composed of trabeculae, and it is found in the interior of a bone. The structure of cancellous bone is presented in Picture 1. The axial skeleton (e.g., pelvis, spine, and ribs) is largely made up of cancellous bone. Cortical bone is dense and hard bone tissue which forms the external layer of all bones and is the largest component in long bones. The appendicular skeleton (e.g., arms and legs) is predominantly cortical bone tissue. (Tortora & Derrickson, 2018, p. 151; Tidswell, 1998, p. 121)

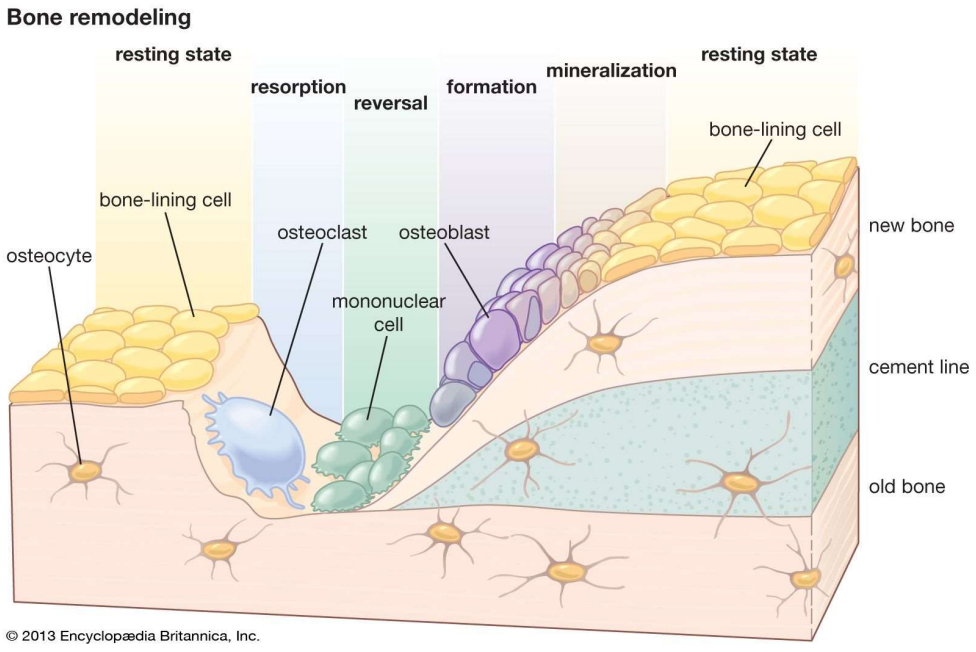


Picture1. Cancellous bone. (Physiopedia - Mechanical Loading of Bone, 2022)

There are four types of cells in the bone: osteoprogenitor (or osteogenic) cells, osteocytes, osteoblasts, and osteoclasts. Osteogenic cells are unspecialized stem cells that develop into osteoblasts. Osteoblasts are responsible for bone formation (osteogenesis). Osteocytes (90-95% of all bone cells) maintain bone tissue and bone metabolism. Osteoclasts are responsible for bone resorption, the breakdown of bone matrix to release minerals (e.g., calcium) into the blood stream. (Tortora & Derrickson, 2017; pp. 150, 158)

3.2 Bone remodeling

Bone is alive tissue that is slowly remodeling throughout human lifespan. As demonstrated in Picture 2 below, bone remodeling (or bone turnover) involves **bone resorption** – destruction of bone tissue by osteoclasts and **bone deposition** – formation of new bone tissue by osteoblasts. Normal bone metabolism – bone growth in childhood/adolescence and bone remodeling in adulthood – depends on various factors. For example, adequate intake of minerals and vitamins from food as well as sufficient levels of several hormones. (Tortora & Derrickson, 2018, p. 158, 160)



Picture 2. Bone remodeling (Britannica, T. Information Architects of Encyclopaedia, 2013)

Osteoblasts and osteoclasts are regulated by hormones, such as parathyroid hormone (PTH), calcitonin and estrogen, and various cytokines (Bolster, 2023). As demonstrated in Figure 1 below, the blood calcium levels are regulated by PTH and calcitonin. When the blood calcium levels are low, parathyroid gland produces PTH, which stimulates the release of calcium from bones into the bloodstream. PTH increases the activity of the osteoclasts, which leads to increased bone resorption and reduced bone formation. Moreover, PTH stimulates the secretion of calcitriol (active form of vitamin D) in the kidney enhancing calcium absorption in the small intestine. PTH also reduces the calcium loss in urine. Calcitonin acts as the opposite of PTH. Its secretion is increased when the blood calcium levels are high. Calcitonin reduces the blood calcium levels by inhibiting the activity of the osteoclasts, preventing bone resorption. (Tortora & Derrickson, 2018, p. 163; Yu & Sharma, 2023)

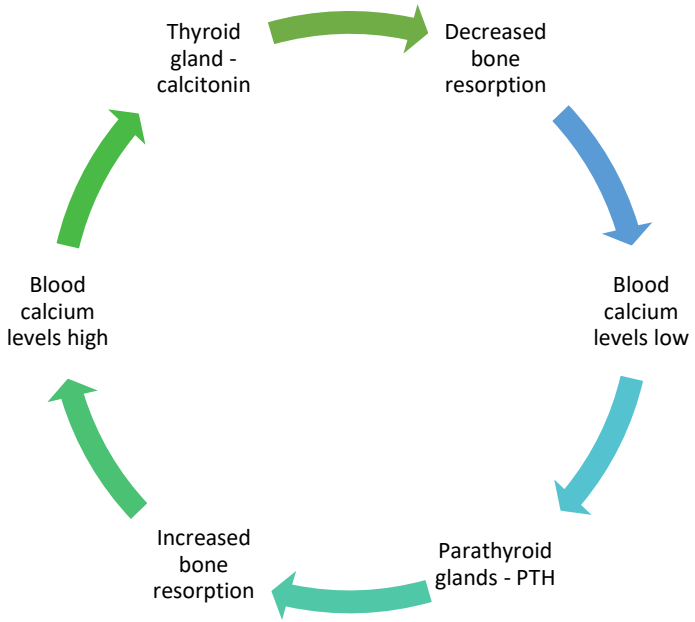


Figure 1. Blood calcium level regulation. (Adapted from Tortora & Derrickson 2018, p. 163, Yu & Sharma 2023)

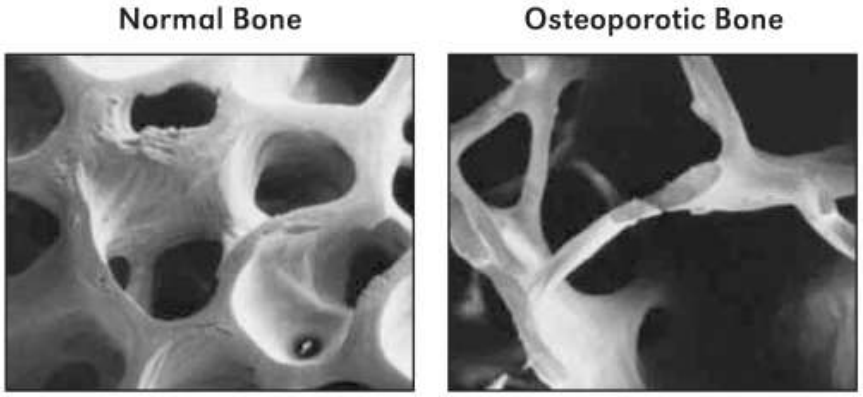
Estrogen is important during bone growth, and it is also a part of the regulation of bone remodeling later in life. Estrogen deficiency in childhood results in increased formation of osteoclasts and increased bone resorption (Väänänen & Härkönen, 1996). Additionally in adulthood, estrogen inhibits resorption by promoting apoptosis, which refers to the death of osteoclasts (Tortora & Derrickson, 2018, p. 160). Osteocytes regulate bone formation and remodeling by transmitting signals to osteoclasts and osteoblasts. This occurs through the secretion of various cytokines. For instance, at the sites of specific mechanical stress, osteocytes produce less sclerostin, a cytokine which functions as a powerful inhibitor of bone formation. Due to less sclerostin, bone formation is increased at that site. (LeBoff et al., 2023)

3.3 Pathophysiology of osteoporosis

In healthy young adults the bone remodeling is in balance and osteoblasts form new bone tissue at the same rate as the osteoclasts destroy it. As people age, the levels of gonadal hormones (estrogen and testosterone) decrease. This results in increased resorption by osteoclasts and reduced deposition by osteoblasts – more bone is resorbed than new bone is formed. Over time, this imbalance in bone remodeling leads to demineralization of bone, the loss of calcium and other minerals in bone matrix, as well as decreased rate of protein synthesis – loss of bone mass and changes in the structure of the bone (brittleness). The loss of bone mass and brittleness of the bone can result in osteoporosis and increase the risk of fractures. (Talvitie & Savola, 1997, pp. 10, 11; Tortora & Derrickson, 2018, p. 164) In secondary osteoporosis, the deficiency or imbalance in hormones, minerals or vitamins is caused by another medical condition or medication – see Table 1 (Bolster, 2023; Ganesan et al., 2023; Osteoporoosi: Käypä hoito -suositus, 2020).

Osteoporotic bone loss effects both cortical and cancellous bone. Cortical thickness decreases and the number and size of trabeculae in cancellous bone reduces. The effect of osteoporotic bone loss in cancellous bone tissue is demonstrated in Picture 3 below. This leads to increased porosity and to skeletal fragility. The resorption is faster in cancellous bone due to its porosity and higher surface area in relation to mass.

Therefore, bone loss becomes apparent earlier at skeletal sites rich in cancellous bone, such as the spine. (Bolster, 2023; LeBoff et al., 2022)



Picture 3. Normal bone vs Osteoporotic (Bone Health and Osteoporosis: A Report of the Surgeon General. Rockville, 2004)

3.4 Risk factors

Osteoporosis is a hereditary disease. Twin and family studies have found that up to 60-80% of BMD is determined by genetic factors. Therefore, family history of osteoporosis is one risk factor of osteoporosis. Specifically parental history of hip fracture is associated with the increased risk. (Bolster, 2023; Huang et al., 2015)

One of the main risk factors associated with developing osteoporosis is age. Although people of all ages can develop osteoporosis, the risk increases with aging (NIH, n.d.). On average the peak bone mass is reached at the age of 30, the bone mass then plateaus for about 10 years. People start to lose their bone mass around at the age of 40 and the deterioration continues as people age. It is estimated that approximately 44% of over 65-year-olds have decreased BMD, osteopenia, or osteoporosis. (Osteoporoosi: Käypä hoito -suositus, 2020)

Another risk factor for developing osteoporosis is female sex. Women are more likely to develop osteoporosis than men. This is partly due to women's smaller bones and lower peak bone mass. Moreover, women's bone loss accelerates during menopause due to decreased levels of estrogen. Postmenopausal women are therefore at higher risk of developing osteoporosis. Overall, on average women lose 50% of cancellous

bone mass and 30% of cortical bone mass. In men the equivalent values are 30% and 20%. (NIH, n.d.; Osteoporoosi: Käypä hoito -suositus, 2020)

Furthermore, among premenopausal women, undereating and excessive physical activity can result in the absence of periods. The absence of periods may cause estrogen deficiency and subsequently increase the risk of reduced bone mass. (NIH, n.d.) Additionally, a low BMI (body mass index) has been identified as a risk factor for developing osteoporosis. Research has found a correlation between body mass and bone mass (Battafarano et al., 2020). Thus, an inherited slender built and thin bones or malnourishment can predispose to bone loss. However, obesity (BMI of 30 or higher) has shown to increase the loss of BMD at the femoral neck (Ganesan et al., 2023).

In addition, insufficient levels of certain minerals (most importantly calcium) and vitamins (especially vitamin D) can predispose to osteoporosis. When bones are growing during childhood and adolescence, large amounts of calcium and phosphorus are required. These minerals are also needed during bone remodeling. Vitamin D increases the absorption of calcium in the gastrointestinal tract into the blood and thus assists bone forming. (Tortora & Derrickson, 2018, p. 160). Inadequate calcium and vitamin D intake during growth can result in reduced peak bone mass. In older people, low levels of calcium and vitamin D have been shown to increase the risk of bone loss. (Talvitie & Savola, 1997, p. 15, 16; Tortora & Derrickson, 2018, p. 157)

Moreover, lifestyle factors such as smoking, excessive alcohol consumption and physical inactivity are risk factors for osteoporosis. Research shows that smoking reduces BMD (Cusano, 2015; Ward et al., 2001). Additionally, smoking can increase the risk of early menopause in women and thus predispose to bone loss (Whitcomb et al., 2018). Excessive and long-term use of alcohol has been shown to inhibit the osteoblastic activity of bone increasing the risk of developing osteoporosis. Bone needs mechanical stress to grow, and thus physical activity is important regarding bone health. Therefore, sedentary lifestyle and immobility increase the risk of osteoporosis. (Bolster, 2023).

3.5 Symptoms and signs

Often the first sign of osteoporosis is a fragility fracture – a low energy fracture, typically of the hip, spine, or wrist. (Fragility fractures and their symptoms are discussed in more detail in section 4.) Without a fracture, osteoporosis is asymptomatic. However, there are signs that may indicate osteoporosis when fracture is asymptomatic and not yet diagnosed. These signs include, loss of height (more than 4 cm), changes in posture: increased thoracic kyphosis (dowager's hump), or pains originating from bones (e.g., during palpation). (Bolster, 2023; Osteoporoosi: Käypä hoito -suositus, 2020)

3.6 Diagnosing of osteoporosis

Typically, a dual-energy x-ray absorptiometry (DXA) is used to measure lumbar spine or hip BMD in the diagnosing of osteoporosis. DXA scan is recommended if: 1) patient has a fragility fracture, 2) patient has a medical condition or other factors which increase the risk of bone loss, 3) there are indications of osteoporosis in X-ray (changes in the vertebrae, signs of calcium deficiency), 4) patient has lost height (at least 4cm) and/or has increased thoracic kyphosis. Moreover, BDM measurement is recommended among children with repeated fractures. (Osteoporoosi: Käypä hoito -suositus, 2020)

The diagnosis of osteoporosis is determined by the T-score of a BMD scan. The T-score is the number of standard deviations above or below a reference value. According to World Health Organization (WHO), normal T-score is -1.0 or higher, T-score between -1.0 and -2.4 indicates osteopenia, and T-score of -2,5 or lower represents osteoporosis. (Kisner et al., 2017, p. 347; Osteoporoosi: Käypä hoito -suositus, 2020) Moreover, T-score of -2.5 or lower, accompanied with at least one fragility fracture, is considered severe osteoporosis (Compston et al., 2017).

4 FRAGILITY FRACTURES

Osteoporotic, or fragility fractures are resulted from minor trauma, from situations where healthy bone would not break, such as falling out of bed. Most commonly, fragility fractures occur in the hip, spine, and wrist. (Bolster, 2023) In Finland, it is estimated, that brittleness of the bone is one of the contributing factors for about 30 000-40 000 fractures that occur every year. In comparison to the general population, the risk of a new fracture is 2-4 times higher in people with a history of a fragility fracture. The incidence of fragility fractures increases exponentially with age. (Osteoporoosi: Käypä hoito -suositus, 2020)

4.1 Hip fracture

Out of all the osteoporotic fractures, hip fracture is the most burdensome to the public healthcare. It requires hospital care without exception, and in most cases surgical treatment. In Finland, approximately 6 000 hip fractures are operated every year. Most hip fractures, over 90 % of them, are caused by a fall. Fracture of the hip is most common among older people: three out of four hip fracture patients are over 75-year-old. (Lonkkamurtuma: Käypä hoito -suositus, 2017; Talvitie & Savola, 1997, p. 23)

A hip fracture leads to decreased functional capacity and increased mortality. Approximately 20% of hip fracture patients require extra care due to reduced functioning. (LeBoff et al., 2022) The increased mortality is due to complications resulted from the surgery and by the immobility during recovery. Therefore, it is important part of postoperative care to mobilize the patient as soon as possible. (Talvitie & Savola, 1997, p. 24)

4.2 Vertebral fracture

Vertebral compression fractures can be difficult to detect because they are often asymptomatic or cause only mild back pain. In case more severe symptoms arise, they usually begin with sudden back pain which forces the person to bedrest or to seek medical help. Typically, the pain is aggravated upon weight-bearing (e.g., standing and sitting) and reduced when lying down. Even minor stresses, such as coughing, sneezing and defecation can increase the pain. The pain is usually present around the midback or upper pelvis area, and it does not radiate to lower extremities. (Bolster, 2023; Talvitie & Savola, 1997, pp. 24, 25)

The reoccurrence of vertebral fracture is high: over 85 percent of patients experience another vertebral fracture within 10 years from the original fracture. Multiple compression fractures often lead to increased thoracic kyphosis and over extension of cervical spine. The abnormal strain on the spinal muscles may cause back and neck pain. In addition, thoracic kyphosis can limit the expansion of the ribcage and reduce lung capacity leading to shortness of breath. (Bolster, 2022; Talvitie & Savola, 1997, p. 25)

4.3 Wrist fracture

Most fractures of the forearm occur at the head of the radius (Colles' fracture). This type of fracture typically happens when a person falls on top of their extended arm. Wrist fractures are five times more common in women than men. Compared to other fragility fractures, they tend to occur earlier in life (between the ages of 50 and 60). A wrist fracture requires medical care, and it is typically treated conservatively with casting for 4-6 weeks. Sometimes surgical treatment is necessary prolonging the recovery period. Although less disabling than hip and vertebral fractures, wrist fracture often leads to reduced quality of life – causing pain and limiting activities of daily living (LeBoff et al., 2022; Värttinäluun alaosan murtuma: Käypä hoito -suositus, 2023).

4.4 Fracture Risk Assessment tool (FRAX)

Patient's fracture risk can be assessed with Fracture Risk Assessment tool (FRAX). Based on patient's clinical risk factors, FRAX predicts the likelihood (%) of fragility fracture for the next 10 years. The factors considered in the questionnaire are presented in Figure 2 below. The tool can be used to guide treatment decisions with postmenopausal women or men over the age of 50 with decreased bone density (osteopenia), but who are not currently taking osteoporosis medication. For instance, if the FRAX score is above certain thresholds, pharmacologic therapy is generally recommended. However, there are some limitations to the use of FRAX as, for instance, the patient's increased falls risk, BMD at the lumbar spine, or family history of vertebral fractures, are not considered in the scoring. (Bolster, 2023; Osteoporoosi: Käypä hoito -suositus, 2020)

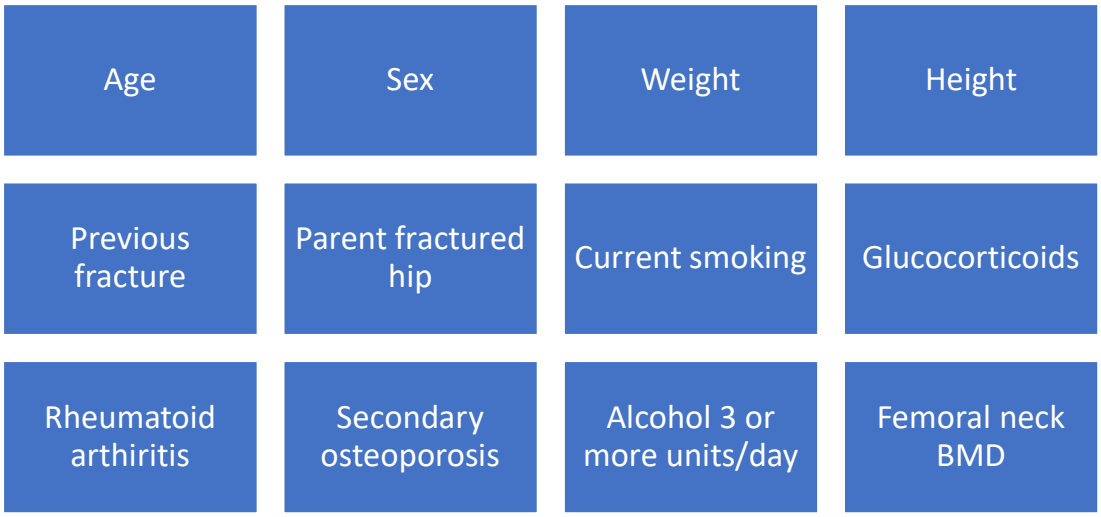


Figure 2. Patient's risk factors considered in the FRAX questionnaire. (Adapted from Centre for Metabolic Bone Disease, University of Sheffield, UK)

5 PREVENTION AND TREATMENT OF OSTEOPOROSIS

Prevention of osteoporosis includes eating foods that are good for bone health (e.g., fruits and vegetables), ensuring adequate intake of calcium and vitamin D, performing regular PA and exercise. Additionally, lifestyle factors such as avoidance of smoking and drinking alcohol in moderation, are ways to prevent osteoporosis. (BHOF, 2018) All of these strategies to prevent osteoporosis are also part of its management. In addition, treatment of osteoporosis can include pharmacological therapy and fall prevention measures. Moreover, regarding PA and exercise among people with osteopenia or osteoporosis, there are factors that should be considered to ensure the safety of the exercise. (PA and exercise will be discussed in more detail in section 6.) (Bolster, 2023; Osteoporoosi: Käypä hoito -suositus, 2020)

5.1 Calcium and vitamin D

Calcium is the most important building material for bones, and it is needed in all stages of life. It is recommended for all men and women to consume at least 1000 mg of calcium per day. For postmenopausal women and older men, the recommended amount is 1200 mg per day. Higher calcium intake is sometimes also recommended during puberty, pregnancy, and lactation. Ideally the calcium is gathered from dietary sources, for example dairy products – one glass of milk (250ml) contains about 300mg of calcium. Other foods that are rich in calcium include, salmon, green leafy vegetables, almonds, and chia seeds. Supplements can be used in case the calcium intake from food is insufficient. (Bolster, 2023; LeBoff et al., 2022; NHS, 2020; Osteoporoosi: Käypä hoito -suositus, 2020)

Moreover, sufficient levels of vitamin D are important regarding bone health. The storage form of vitamin D, S-25(OH)D, is measured to determine the body's vitamin D levels. The interpretation of blood vitamin D values is presented in Table 2 below. One important source of vitamin D is the sun – the skin produces vitamin D3 (cholecalciferol) when exposed to direct sunlight. During the winter months, vitamin D can be gathered from foods and from supplements. Fortified edible fats and liquid

dairy products as well as fish are the most important dietary sources of vitamin D. According to Finnish Food Authority (2022), the recommended daily intake of vitamin D for adults is 10 µg and 20 µg for people over the age of 75. To add, vitamin D supplements are recommended especially for people aged 75 and older, for pregnant and lactating women as well as for people who do not consume fish or fortified edible fats or dairy products. (LeBoff, 2022; Finnish Food Authority, 2022; Osteoporoosi: Käypä hoito -suositus, 2020)

Table 2. Interpretation of blood S-25(OH)D values. (Adapted from Osteoporoosi: Käypä hoito -suositus, 2020)

S-25(OH)D	**Interpretation**
< 25 nmol/l	Severe vitamin D deficiency
50-75 nmol/l	Sufficient vitamin D levels
> 120 nmol/l	Too much vitamin D

5.2 Pharmacological therapy

Before pharmacological therapy can be started, the patient's calcium and vitamin D levels should be at adequate levels. Medications for osteoporosis include antiresorptive medications (e.g., bisphosphonates, denosumab, and estrogen), anabolic agents, and romosozumab. The effectiveness of antiresorptive medications is based on the inhibition of bone resorption. Bisphosphonates prevent bone remodeling (bone turnover) and denosumab is an antibody against RANKL, a cytokine that is needed in osteoclast formation. Estrogen therapy can preserve BMD; however, the use of estrogen is associated with a higher risk of blood clots and endometrial cancer. Additionally, estrogen therapy may increase the risk of breast cancer. Anabolic agents stimulate bone formation and can be considered in situations where the patient cannot tolerate antiresorptive medications or they are shown to be ineffective. Romosozumad stimulates bone formation by blocking sclerostin, a cytokine produced by osteocytes that reduces bone formation. (Bolster, 2023; LeBoff et al., 2022; Osteoporoosi: Käypä hoito -suositus, 2020)

5.3 Fall prevention

Majority of fragility fractures are resulted from a fall, thus fall prevention is important part of osteoporosis management (Brooke-Wavell et al 2022). Fall prevention measures are relevant especially among osteoporotic people who have an increased risk of falls. Risk factors for falls can be divided into intrinsic and extrinsic (or environmental) factors. Intrinsic risk factors of falls, include reduced muscle strength and mobility, impaired vision as well as poor dynamic and static balance. Whereas poor lighting and uneven or slippery surfaces, are examples of extrinsic (or environmental) risk factors of falls. (Appeadu & Bordoni, 2023; Osteoporoosi: Käypä hoito -suositus, 2020)

Fall prevention measures include patient education, for instance giving information on the risks of falls and fractures, instructing how to perform activities of daily living (ADLs) safely, as well as giving guidance regarding appropriate nutrition and PA. Additionally, to reduce the risk of falls exercises to improve balance, muscle strength and mobility can be given to the patient. The exercises should be individual and based on the assessment of the patient's physical and functional capacity. Furthermore, fall prevention measures can include assistive aids to support walking (e.g., rollator) and modifications to home environment (e.g., removing carpets, installing handrails). (Bolster, 2023; Suomen fysioterapeutit, 2017)

6 PHYSICAL ACTIVITY AND EXERCISE

Physical activity (PA) is an important part of prevention and treatment of osteoporosis. Mechanical loading during weight-bearing impact activity and resistance training, has shown to increase BMD and strengthen the bones. Moreover, improving muscle strength and balance can improve functional capacity and reduce the risk of falls. Additionally, strengthening of the spinal muscles might reduce pain and kyphosis in patients with vertebral fractures. (Bolster, 2023; Brooke-Wavell et al., 2022)

As presented in Figure 3 below, PA and exercise are important for bone health throughout life – from childhood until old-age. In childhood and adolescence, PA and exercise can strengthen the bones and increase the peak bone mass. In adults, it can help maintain or increase BMD and among older population it seems to reduce the effects of age-related bone loss. (Kisner et al., 2018, p. 349)

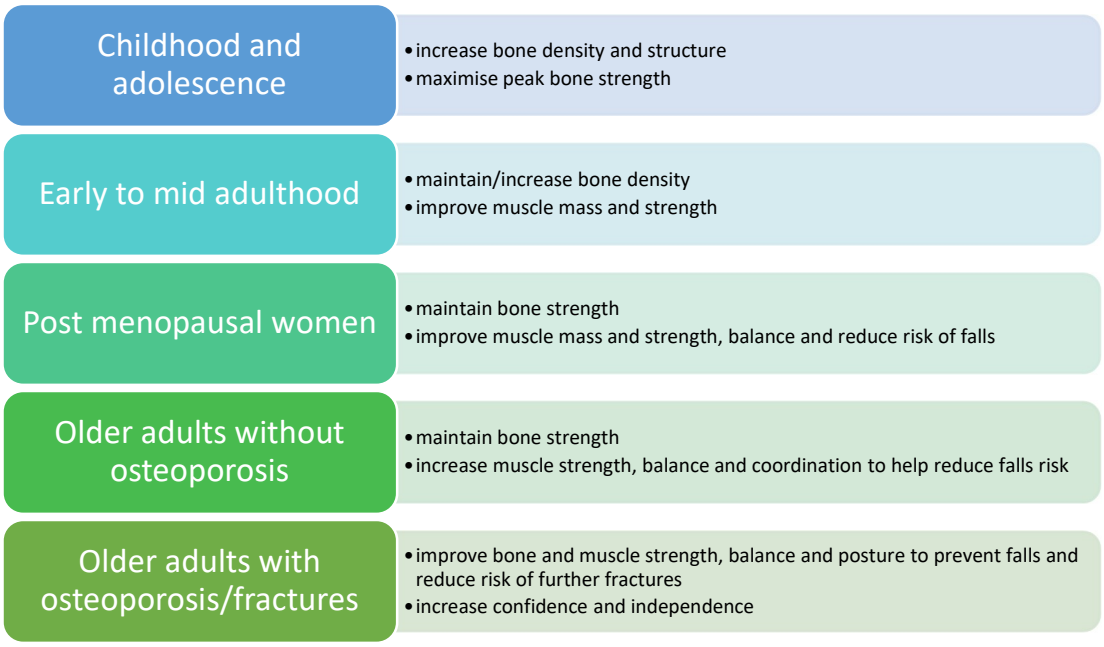


Figure 3. Role of exercise in bone health at different stages of life. (Recreated from Godwin, 2017)

6.1 Mechanical loading

Mechanical stress on the bone stimulates osteogenesis – formation of new bone tissue. Mechanical forces that act on the skeleton during PA are produced either from the impact with the ground (ground-reaction or gravitational forces) or from the muscle contraction (muscle-joint forces) (Morseth et al., 2011). How the bone responses to the mechanical stress depends on various factors, such as the magnitude, rate, distribution (pattern) and number of loading cycles (Nikander et al., 2010). The load put on bones during PA can be measured in terms of multiples of body weight (MOB). Although, most PA loads bone to some extent, to cause strong osteogenic stimulation, the load caused by the activity should be around 4 MOB. (Brown, 2018)

6.2 Weight-bearing aerobic exercise

Weight-bearing activity can be defined as any activity that is performed on one or both feet, and during which the skeletal system is working against gravity (Anderson et al., 2018). Low-impact weight-bearing activities include, for example, walking and Thai Chi, whereas activities such as, running, jumping, aerobics, ball games, and dancing are examples of moderate- or high-impact weight-bearing activity. Although low-impact aerobic exercise has various other health benefits (e.g., cardiovascular health), to best promote bone health, a sufficient gravitational force needs to be produced during the impact activity. (Brooke-Wavell et al., 2022)

A systematic review and meta-analysis by Nikander et al. (2010) concluded that for children the most effective exercise program to improve bone strength, includes a combination of multidirectional moderate- to high-impact weight-bearing activities (e.g., skipping, dancing, jumping, and hopping). The suggested magnitude for the exercise is 3-9 MOB and these activities should be performed three to five times per week, for 10-45 minutes per session (Nikander et al., 2010). Similarly, the UKK Institute's PA recommendation for bone health, states that children and adolescents should partake in PA which includes variety of jumps and rapid direction changes (e.g., stick and ball games, athletics, or gymnastics). According to the UKK Institute's

recommendation, this type of activity should be performed three times per week, 60 minutes at a time. Moreover, adequate number of jumps is stated to be 50-100, which can be divided into few separate sessions (UKK Institute, n.d.).

For adults, weight-bearing impact activity is recommended on most days (or 4-7 days/week), and each session should include at least 50 jumps (Beck et al. 2016; Brooke-Wavell et al., 2022). It should be noted that high-impact activity increases the risk of injuries. Therefore, due to decreased bone mass and more fragile bones, moderate-impact activity might be more suitable for people with osteopenia and osteoporosis. For instance, an Australian guideline by Beck et al. (2016) recommends high-impact exercise (>4 MOB) for people without osteoporosis, but for people with moderate risk of osteoporosis the recommended impact level is 2-4 MOB. UK consensus statement by Brooke-Wavell at al. (2022) recommends moderate-impact activity for healthy people as well as for people with reduced BMD. The recommended activities include jumping, running and higher impact forms of dancing (e.g., zumba) and ball games. However, very high impacts such as landing from height should be avoided. (Brooke-Wavell et al., 2022)

Furthermore, with regards to moderate-impact activity, more caution might be needed with osteoporotic people who have vertebral fractures or multiple fragility fractures. The factors that should be contemplated include the number of vertebral fractures and associated symptoms, possible other medical conditions, and the patient's overall fitness level. Patient's previous experiences with moderate-impact activity should also be considered. (Brooke-Wavell et al., 2022) Additionally, according to Sherrington et al. (2017) even low-impact activity (e.g., brisk walking) may further increase fracture risk in older people already at higher risk of falls. Thus, in this population, strength and balance training to improve stability might be required before impact activity can be started (Brooke-Wavell, 2022).

Walking is one of the most common forms of weight-bearing aerobic exercise (Benedetti et al., 2018). Comprehensive research has been done on the effects of walking on BMD, however the results are not consistent in the studies (Martyn-St James & Carroll, 2008; Daly, 2017; Nikander et al., 2010). A meta-analysis by Martyn-St James and Carroll (2008) assessed the effects of walking programs on BMD at hip

and spine sites in postmenopausal women. It concluded that regular walking has no significant effect on BMD at the spine, but at femoral neck the effects on BMD were positive. According to some studies, however, walking as a sole form of exercise showed no significant effects on the BMD at the hip or at the spine (Daly, 2017; Nikander et al., 2010).

A study by Roghani et al. (2013) evaluated the effects of aerobic exercise with and without external loading on bone metabolism and balance in postmenopausal women with osteoporosis. In the study, the participants were randomly divided into three groups: aerobic, weighted vest and control. The exercise programs of the aerobic and weighed vest groups were identical except the latter carried weighted vests (4-8% of body weight). The results demonstrated that both exercise groups had increased bone formation and decreased bone resorption, but exercising with external load was better for improving balance. (Roghani et al., 2013)

Furthermore, the benefits of Tai Chi practice on bone health have been studied in recent years (Chow et al., 2017; Sun et al., 2016; Zou et al., 2016). Although the evidence is sometimes weak and inconsistent (Sun et al., 2016), Thai Chi may be beneficial in reducing BMD loss at the lumbar spine and at the hip among certain populations (Zou et al., 2017). Research suggests that the positive effects are better seen in long-term Thai Chi practice (Chow et al., 2017). Moreover, Thai Chi practice has shown to prevent falls and is therefore recommended for people with osteoporosis (Sherrington et al, 2019).

6.3 Resistance training

Resistance training is any exercise that uses resistance, such as weights, bands, or body weight, to cause muscle contraction. Resistance exercise can be used to improve muscle strength, muscle power, and/or muscle endurance. (Kisner et al., 2018, pp. 167, 168) Its effect on BMD and bone strength is based on the mechanical stimulus that is produced during muscle contraction (Benedetti et al., 2018). When muscle contracts, a pulling force is generated to the bone that the muscle attaches to – the tendon pulls on the bone creating a mechanical stress. Moreover, stronger, and bigger muscles pull

harder on the bones, and thus promote bone strength. (Royal Osteoporosis Society, n.d.) Resistance training is sometimes defined as “nonimpacting” and it can be performed with loading (e.g., lifting weights) or without loading (e.g., swimming and cycling) (Benedetti et al., 2018). Strength and resistance training that is performed with loading is ideally performed under supervision to ensure correct technique and to minimize the risk of injury. (Beck et al., 2017; Brooke-Wavell et al., 2022; Giangregorio et al., 2014)

The effects of resistance training on BMD and bone strength have been studied widely among adults and older people (Bolam et al., 2013; Massini et al., 2022; O’Bryan et al., 2022; Pinheiro et al., 2020). A study by Bolam et al. (2013) found that resistance training alone or together with impact activity is the most osteogenic among middle-aged and older men. Additionally, a systematic review by Pinheiro et al. (2020) found that exercise programs involving multiple types of exercises or resistance exercises seemed to best promote bone health. To add, the review found that effects of resistance training on BMD were better demonstrated at the lumbar spine than at the hip (Pinheiro et al., 2020). Whereas a study by O’Bryan et al. (2022) indicates that progressive resistance training seems to improve the lower-limb muscle strength as well as the BMD at the hip among older adults. In contrast, a systematic review and meta-analysis by Massini et al. (2022) found that resistance training seems to have no effect on increasing the BMD in healthy older people, but that it might help preserve bone mass in this population.

Research suggests that the benefits of resistance training on BMD are site-specific (Benedetti et al., 2018; Zehnacker et al., 2007), thus, the exercises should load skeletal sites at the risk of fragility fracture (Brooke-Wavell et al., 2022). Beck et al. (2016) recommends eight exercises targeting major muscle groups, such as lunges, hip abduction/adduction, knee extension/flexion, back extension, reverse chest fly, and abdominal exercises. Brooke-Wavell et al. (2022) suggests that some of these exercises could be replaced by fewer compound movements, for example squats and deadlifts. Stress during spinal flexion increases the risk of vertebral compression fracture (Kisner et al., 2018, p. 349, 350). Therefore, it is important to note that among people with osteopenia or osteoporosis, loaded spinal flexion (e.g., crunches, sit-ups,

and the use of abdominal machines) should be avoided or at least modified (Beck et al., 2018; Brooke-Wavell et al., 2022).

Furthermore, higher intensity resistance training seems to be more beneficial in improving BMD and bone strength (Beck et al., 2016; Giangregorio et al., 2014; Zehnacker et al., 2007). A systematic review by Zehnacker et al. (2007), found that to improve BMD at the hip and spine high loads are required, 70-90% of 1 RM for 8-10 repetitions of 2-3 sets. High intensity resistance training is also recommended in guidelines: 8-12 repetitions maximum (RM) – meaning the maximum weight that could be lifted for 8-12 times (Beck et al., 2016) and 8 repetitions at 80-85% of 1 RM (Giangregorio et al., 2014). To improve bone strength and muscle performance, resistance training needs to be progressive. This means that the loading (intensity or volume) of the exercise should be gradually increased. However, progressive overload should be done within the structural capacity of the bone. It might be appropriate to start with lower intensity exercise and gradually increase the loads once the correct technique is ensured. (Brooke-Wavell, 2022; Kisner et al., 2018, pp. 349, 350)

Moreover, strengthening exercises for the spinal extensors are recommended for people with reduced bone mass to improve posture (reduce kyphosis) and to prevent fractures. Moreover, these exercises can relieve pain, reduce muscle spasms, and improve flexibility among osteoporotic people with vertebral fractures. For people who have vertebral fractures, these exercises are recommended to be done daily and the exercises should be done with low intensity with a focus on muscle endurance. People without vertebral fractures should aim to perform back extension exercises at least twice a week. (Brooke-Wavell et al., 2022)

A study by Sinaki et al. (2002) demonstrated the long-term effects of strong back muscles in reducing the risk of vertebral fractures in postmenopausal women. Moreover, A study by Huntoon et al. (2008) found that strengthening of the spinal muscles with back extension exercises, after vertebral surgery following a fracture, positively affected the refracture rate. This retrospective analysis of medical records demonstrated that the group who did not perform back extension exercises refractured within 4.5 months, whereas the exercise group’s average time to refracture was 20.4 months. (Huntoon et al., 2008)

6.4 Safety of physical activity and exercise in people with osteoporosis

Recent research demonstrates that PA and exercise can be carried out safely among people with osteoporosis (Harding et al., 2020; Kunutsor et al., 2018; Watson et al., 2019). Systematic review by Kunutsor et al. (2018) found no evidence indicating a connection between impact exercise or moderate- to high-intensity resistance training and vertebral fractures. However, certain movements that require extreme spinal (e.g., certain yoga position) flexion were shown to possibly increase the risk of vertebral fracture (Kunutsor et al, 2018). Additionally, supervised resistance and impact training among people with osteoporosis seems to be associated with only a few adverse effects such as muscle and joint discomfort, and no vertebral fractures (Harding et al., 2020; Watson et al., 2019).

Healthcare professionals tend to be extremely careful when guiding PA and exercise for those with osteoporosis. Additionally, the patients with reduced bone mass often associate exercising with increased risk of falling and fractures, and therefore restrict their PA. (Kunutsor et al., 2018) Moreover, patients who have symptomatic vertebral fractures often fear that movement will increase their pain, when in reality exercise has the opposite effect. Consensus statement by Brooke-Wavell et al. (2022) suggests a positive and encouraging approach toward exercising – instead of telling people "don't do" guiding them "how to". Correct form and technique are especially important in exercising among people with osteoporosis to reduce the risk of fractures. Safe techniques that can be applied to everyday life as well as to exercise include, lifting and bending with straight back – instructing how to use hip hinge to enable this, and engaging the core muscles during movements to protect the spine. (Brooke-Wavell et al., 2022)

According to Brooke-Wavell et al. (2022), there is a little need for adaptations to exercise of those people who have reduced BMD, but who do not have fragility fractures. Even sports that have an inherent injury risk (e.g., contact sports and skiing) seem to have greater benefits on muscle and bone strength compared to their risks. Thus, people with reduced bone mass who regularly practice these types of sports, should be encouraged to continue among their hobbies. More caution is needed among

osteoporotic people who have fragility fractures and those who are more prone to falls. However, all people with osteoporosis should be encouraged to move and exercise within their physical capacity. For instance, for some patients with osteoporosis (e.g., those at increased falls risk) the focus might be on muscle strengthening and balance training with the goal to prevent falls. Whereas, for those who are frail and less able to exercise, this might mean limiting sedentary behavior, the time spent sitting or lying down, as much as possible. Additionally, (Brooke-Wavell et al., 2022)

7 THESIS PROCESS AND METHODS

The thesis was ordered by Satakunta University of Applied Sciences (SAMK) English Degree program in Physiotherapy. The methodology of the thesis was action-based research: an independent learning material for students was created based on evidence-based theoretical knowledge. The methods of the thesis were chosen due to author's preference and to best achieve the aim and objectives of the thesis.

Thesis process began in September 2022 by collecting ideas for the topic and in December 2022 the topic was chosen. The topic was chosen due to a need for an independent learning material regarding osteoporosis in SAMK's English Degree program in Physiotherapy and due to the author's interest in the topic. Osteoporosis is a common disease and physiotherapy has an important role in its prevention and treatment. Additionally, the topic of osteoporosis was addressed only superficially during the studies. Therefore, the author believed that such material would be needed. The thesis plan was put together and presented in January 2023. The research for the theoretical background of the thesis began in March 2023. After researching more on the topic, the structure of the thesis started to take shape during summer 2023. The writing of the theory part of the thesis began in September 2023 and continued until November 2023 and subsequently the independent learning material was created and piloted. Finally, the presentation of the thesis occurred in December 2023.

Methods of the thesis were to gather evidence-based information from books, guidelines, consensus statements, articles, and other publications. The author used databases such as PubMed, Google Scholar, and Cochrane Library, to gather the evidence. Key search terms included "pathophysiology of osteoporosis", "osteoporosis and physical activity", and "effects of exercise to BMD and bone strength". The research was done in English and in Finnish. To ensure high level evidence, the author focused on systematic reviews and meta-analyses that were peer reviewed. For the prevention and treatment part of the thesis, the inclusion criteria were adults with reduced bone mass and adults with normal bone mass. The exclusion criteria for this part of the thesis were osteoporosis in children.

8 IMPLEMENTATION OF THE INDEPENDENT LEARNING MATERIAL

The independent learning material was created on Moodle H5P platform, in the form of an interactive book. The author had participated in the piloting of other student's H5P materials in the past and had found them to be informative and educational. Such material allows students to deepen their knowledge on topics which are not discussed in detail during the courses' contact hours. The material was created in a way that it would be easy to follow and understand – using figures, and pictures as a visual element. After each section, a few multiple choice- and true/false questions were added to ensure that the students have understood the information and to make the material more interactive.

The H5P material was piloted by third- and fourth-year international students from Satakunta University of Applied Sciences. International students were chosen because the material was done in English. Overall, 10 students showed an interest in participating in the piloting process, which took place 20.11.2023-29.11.2023. To ensure anonymity, Google forms questionnaire was used to collect feedback. The feedback form included three simple statements which were graded from 1 (completely disagree) to 5 (completely agree). Additionally, at the end of the feedback form, the students were encouraged to freely discuss their thoughts regarding the material – what they liked/disliked and why as well as give suggestions on how to improve the material. (Appendix 1)

8 people gave feedback before the deadline, thus the drop out number was 2. Overall, the feedback was positive, and the students found the material to be informative and easy to follow. Suggestions on how to improve the material included adding more visual elements to the material, such as pictures and videos. Based on the feedback and suggestions, the author made some changes to the material. The independent learning material will be added to medical sciences and pharmacology course as part of English Degree program in Physiotherapy.

9 DISCUSSION

The material discussed in this thesis will be included as a part of the medical sciences and pharmacology course. Therefore, the author has chosen to include a rather comprehensive description of the osteoporosis disease profile. It is the author's belief that to treat patients with osteoporosis, a profound understanding of the disease is required. This understanding is also vital to educate and guide people and communities about the importance of bone health as a part of osteoporosis prevention. The author has learnt a lot during the research process. The in-depth exploration of the pathophysiology of osteoporosis, including the effects of minerals and hormones on the BMD and bone strength and their subsequent interconnection with the osteoporosis risk factors, prevention, and treatment, has helped in deepening the author's understanding of osteoporosis as a disease.

One challenge that was encountered by the author during the writing process was deciding how to structure the prevention and treatment parts of osteoporosis into the thesis. The two topics were combined and are discussed side by side due to the predominantly similar strategies utilized in both, the disease's prevention, and its management. For example, when discussing weight-bearing exercise, the most beneficial impact level for bone health is identified along with considerations for people with osteoporosis. PA and exercise have been focused on because physiotherapists' role in particular involves the prescription of exercises as well as advice and guidance regarding PA.

The author chose to focus on PA and exercise that has shown to have positive effects on BMD and bone strength instead of exercising with the goal of preventing falls. The author is aware that fall prevention is covered extensively in other courses during physiotherapy degree program, for instance in the geriatric physiotherapy course. Thus, although an important part of osteoporosis management and fracture prevention, less emphasis was put on discussing fall prevention measures.

Furthermore, on occasion the author found it challenging to navigate through all the recommendations regarding PA and exercise for people who have osteoporosis as the information was at times conflicting. For instance, some sources suggest that all people who have osteoporosis should be extremely cautious when exercising, whereas more recent research seemed to be more encouraging rather than restricting in their recommendations. It was also the author's previous belief that there are many types of exercise that all people who have osteoporosis should avoid. However, the author's view changed during the research process. It seems that instead of giving general instructions to all people with osteoporosis, the focus should be more on the individual.

After researching osteoporosis and understanding the disease better, the author recognizes that osteoporosis is an increasing concern from a public health perspective. The incidence of osteoporosis increases with age and with life expectancy continuing to increase worldwide, consequently the prevalence of osteoporosis also increases. Additionally, children are becoming less physically active – instead of playing outside they spend more and more time on their phones and computers. Overall, people lead more sedentary lifestyles, both in terms of their private and working lives. Jobs continue to involve less and less physical activity or movement in general due to working with computers at office environments.

The aim of this thesis was to increase the knowledge of future physiotherapy students regarding osteoporosis and with this paper along with the independent learning material, the author hopes that the students' knowledge about osteoporosis is enhanced.

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Feedback of the H5P material

Lomakkeen kuvaus

The material was understandable and easy to follow *

	1	2	3	4	5	
Completely disagree	○	○	○	○	○	Completely agree

I gained new evidence-based knowledge from the material *

	1	2	3	4	5	
Completely disagree	○	○	○	○	○	Completely agree

The material provided me with enough information *

	1	2	3	4	5	
Completely disagree	○	○	○	○	○	Completely agree

Please share your thoughts about the H5P material: What did you like/dislike and why? Do you have any suggestions or ideas on how to improve the material? *