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The effectiveness of exercise in the management of osteoporosis in middle-aged women

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ABSTRACT

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Osteoporosis refers to a bone disorder. It is the most common chronic metabolic bone disease. Osteoporosis places disproportionately heavy burden to women. In addition, age is a critical factor in the development of osteoporosis. This means that being female and elderly are both risk factors, which are non-modifiable risks. This led to the emphasis of women over 40 as a target group of my study.

The prevention and treatment of osteoporosis can be either pharmacological or nonpharmacological. As the former does not fall into the competence areas of physiotherapy, my focus in this thesis is on the latter. As exercise has become an important part of osteoporosis management, it has been discussed in this thesis in detail. Thus, the aim of this thesis is to provide healthcare professionals, and most notably physiotherapists, with knowledge of the evidence on the role of exercise in preventing and treating osteoporosis.

The specific objective of the thesis is to review the evidence-based knowledge of anti-osteoporosis exercise. The research question is the following: What is the current evidence of the effectiveness of exercise in preventing and treating osteoporosis in middle-aged or elderly women?

Research strategy follows the procedures of descriptive literature review. The content of the selected articles is analyzed using qualitative content analysis.

Results of this thesis show that there is evidence of the effectiveness of exercise in preventing and treating osteoporosis in middle-aged women. However, analysis has produced mixed results in some respects. The patterns identified in this analysis suggest that the longer period and the higher intensity exercise have a higher probability to produce positive results. The conclusion is that well-designed and tailored exercise programs are likely to be beneficial for postmenopausal women, and that in spite of possible low bone mass they should be encouraged to conduct exercise, including tailored and guided high-intensity exercise.

Keywords: osteoporosis,osteopenia, BMD, women, exercise, physiotherapy

CONTENTS

1 INTRODUCTION

Osteoporosis is commonly seen as one of the most common bone diseases. It occurs more often in women than men, which has given it a special feature as a disease. Even if it is not among the most serious health issues for women, it has emerged as a major public health issue. Regarding gender viewpoint, it is four times more common among women than among men. Women experience also younger onset of bone loss, and it happens at a faster rate than with men. All this relates to the fact that women have on average smaller and thinner bones than men. (Alswat, 2017; Mitek et al., 2019.)

Besides gender, also age is a relevant factor when considering the nature of osteoporosis. Gender and age are actually intertwined. Namely, estrogen, which protects bones, is sharply affected by menopause. For such reasons middle-aged women's issues with osteoporosis have attracted special attention in medicine. Even if osteoporosis is experienced in all age groups and genders, it is most common among older women. Globally, one in three women and one in five men over the age of 50 are likely to experience osteoporotic fractures during their lifetime. Although there are various factors that cause osteoporosis, most fractures occur in postmenopausal women. (Sözen et al., 2017.)

My personal interest in this issue has a connection with my ethnicity, for this topic has been discussed widely in Asia with regard to middle-aged and older women. My initial assumption was that many Asian women do not get high bone mass during the peak time of the bone growth due to cultural habits, lifestyle, and the lack of information about the importance of physical activities and nutrition for bone, such as calcium intake. Current research supports such assumptions to a degree, as it seems that the greatest burden of hip fractures occurs in East Asia (see e.g. Cheung et al., 2016).

After delving into this matter, I found out that the picture of osteoporosis is more nuanced that I initially thought. For example, in the American context Asian-

Americans have the lowest bone density among all ethnic groups. However, for some reason, fracture statistics tells a slightly different story, for postmenopausal Asian-American women have paradoxically the lowest fracture rate among ethnic groups (Barrett-Connor et al., 2005; Tung, 2012). This highlights the complexity of the issue and, particularly, our need to take into account factors that both increase and decrease the risk of fractures. Most striking in this respect is the fact that large part of fractures happens to women who do not have particularly low bone density.

When starting to extend the discussion of this issue from Asian women to other ethnic groups, I found out that especially Caucasians share similar concerns with Asians. Actually, osteoporosis appears to be a genuinely global issue with pervasive impact on women's everyday life especially among middle-aged and older women. The prevalence of the problem is well highlighted with the CDC (Centers for Disease Control and Prevention) statistics, according to which some 13 per cent of women aged 50 to 64 years had osteoporosis in 2017-2018, the figure increasing to some 27 per cent for females aged 65 and above. (Sarafrazi et al., 2021.)

While osteoporosis is already the most common chronic metabolic bone disease, its severity is likely to increase. Population ageing and rising life expectancy increase its severity, even to the extent it may result in global epidemic. (Pouresmaeili et al., 2018). According to some estimates, more than 200 million people worldwide suffer from osteoporosis. (Sözen et al., 2017; Sarafrazi et al., 2021.) According to a meta-analysis, its global prevalence is estimated to be in the region of 18.3 per cent of population (Salari et al., 2021). In the early 2000s, osteoporosis caused more than 8.9 million fractures per year (Johnell & Kanis 2006), which is expected to rise considerably in the coming decades due to ageing of population.

Previous discussion about the nature of osteoporosis leads to two assumptions that are of vital importance for my thesis. First, osteoporosis as a rule places disproportionately heavy burden to women. This justifies a focus on women. Second, age is a critical factor in the development of osteoporosis. This led to the emphasis of women over 40 as a target group of my study.

After the problem with osteoporosis among middle-aged and older women has been identified, it is natural to start considering the ways of addressing the problems in terms of public health and related risk mitigation and of the prevention and treatments as individual-level interventions. This has led to consider the relevance of accurate information on the reasons of osteoporosis as well as its prevention and treatment targeted especially to the middle-aged women. This is particularly important, as bone specialists believe that the healthcare system actually neglects and under-prioritizes osteoporosis and fragility fractures (Bloomer, 2019). Thus, a host of questions can be raised regarding the effective ways of preventing and treating osteoporosis, the impact of exercise and lifestyle choices on the development of osteopenia and osteoporosis, the availability of exercise therapy treatments, and whether there is sufficient evidence to back up exercise intervention as osteoporosis treatments and prevention.

Of such questions I have focused on those that revolve around the question of how physiotherapy can help to prevent or treat osteoporosis among middle-aged women. To address this, my idea is to collect existing evidence-based knowledge on this issue. As pharmacological management of osteoporosis, such as medication and hormonal therapy, is not available for physiotherapy as a health care profession, in this thesis my attention is directed to nonpharmacological treatments, and among them especially exercise (On osteoporosis treatments, see Tu et al., 2018; Goolsby & Boniquit, 2017; Pinheiro et al., 2020; Rondanelli et al., 2021, Papadopoulou et al., 2021).

Seeking knowledge and evidence of nonpharmaceutical interventions is a kind of supplementary strategy in the big picture of health promotion. It is essential that awareness is increased among health care professionals, which in turn facilitates the increase of awareness of ordinary people on this matter (Sözen et al., 2017). It is, however, equally important to adopt a holistic approach to this issue, which emphasizes people's own responsibility of their health and well-being, including lifestyle, nutrition, and exercise (on exercise, see Bonaiuti et al., 2002). Providing knowledge of how lifestyle affects diseases and health problems, and how healthy life choices may reduce risk for diseases, is one of the epistemic preconditions for health-promoting behaviour.

2 AIM AND OBJECTIVES

The aim of this thesis is to provide healthcare professionals, and most notably physiotherapists, with knowledge of the evidence on the role of exercise in preventing and treating osteoporosis.

The specific objective of the thesis is to review the evidence-based knowledge of anti-osteoporosis exercise. The research question is the following: What is the current evidence of the effectiveness of exercise in preventing and treating osteoporosis in middle-aged or elderly women?

The primary focus of this thesis is to find evidence on various forms of exercise that aim at increasing bone density among middle-aged women. Regarding evidence, this paper focused on changes in bone mineral density (BMD) levels at the hip and spine as study outcome after exercise trials. This is because measuring BMD scores are a way to diagnose osteoporosis. In terms of exercise, the focus is on weight-bearing exercise, including walking and jumping as well as supervised strength and weight training. Research design, data collection, and analysis is based on literature review, which is described in detail in methodology section.

3 CONCEPTUALISING OSTEOPOROSIS

3.1 Anatomy and functions of bones

Bones are a rigid form of connective tissue, composed primarily of calcium salts. They constitute most of the skeleton of the body. Human body consists of 206 separate bones. Collectively bones form the skeletal system, also called the musculoskeletal system, which forms a support structure for a human body. Skeletal system is vital for body shape and functions. It provides protection for organs, allows movement, makes

blood cells in the bone marrow, and stores minerals. This is also why bones, as a basic element of this structure, are essential for our functionality and health. (Currey, 2002.)

Bones change during a lifetime, in some respect they improve and in some they deteriorate (Boskey & Coleman, 2010). In essence, humans' ability to maintain bone cells and structures decrease slowly during one's lifetime. Bone cells have their role in maintaining bone homeostasis and related remodelling processes. However, ageing implies that less new bone is formed in bone remodelling, which produce bone loss and may cause structural damage. The bone remodelling goes through age-dependent changes, including increased bone turnover, less new bone formation, increased bone resorption, and an imbalance in bone remodelling, which means that its ability to ensure the continuous replacement of damaged and old bone is slowly weakening. Such a development leads inevitably to reduced bone mass and consequently also increased fracture risk. (Corrado et al., 2020.)

In women, menopause-related estrogen deficiency increases osteoclast formation which induce bone loss. As a result, more bone is resorbed and less bone is formed, which accelerates bone loss and causes a few other negative effects. Such a development is exclusive health concern of women, for men do not have the same kind of midlife event as women (Seeman, 2002). A practical consequence of the age-related bone changes is the increased fracture risk. (Corrado et al., 2020; Boskey & Coleman, 2010.)

3.2 What is osteoporosis?

Osteoporosis is a bone disorder. It affects bone biologic material and causes related bone structural distraction (Pouresmaeili et al., 2018). It is the most common chronic metabolic bone disease (Sözen et al., 2017). It has been characterized as a silent disease, for people are not generally aware of it until fractures occur. This causes various secondary health problems and, in the worst case, even death. (Sözen et al., 2017.)

Osteoporosis refers to decreased bone density, deterioration of bone tissue, and disruption of bone microarchitecture. It leads to bone fragility or compromised bone strength, which increase bone fracture risk. (Sözen et al., 2017.) When fracture occurs, it implies that forces applied to a bone exceed its strength (Troy et al., 2018). It is worth mentioning that osteopenia is a related condition in which bones are weaker than normal but have not weakened to the level of osteoporosis. The BMD test result is given in the form of T-score, in which the lower score correlates with higher bone fracture. The T-score of osteoporosis is -2.5 or lower, while in the case of osteopenia it is between -1 and –2.5. Paradoxically, largest share of fractures actually occur in patients with osteopenia simply because the large number of patients whose T-score are in the osteopenic range (Lems et al., 2011).

In order to be certain that the case is about osteoporosis, it has to be properly diagnosed. Clinically this is usually done by measuring the BMD with dual-energy X-ray absorptiometry (DXA). Bone strength is determined by size, structure, material properties of the bone tissue, and a few other factors. It cannot be measure in its entirety directly in a living person but must be estimated indirectly. Areal BMD (aBMD), which is adjusted for the projected area of the region scanned, is based on a quick and painless dual-energy X-ray absorptiometry (DXA), while volumetric BMD (vBMD) utilizes quantitative computed tomography (QCT) measurements. The latter provides better picture of bone quality, yet its availability is lower than that of DXA. (Troy et al., 2018.) In general, measuring bone mineral density of the hip and spine using DXA is considered the most reliable way to diagnose osteoporosis. On the one hand, Levine (2006) has emphasized the limited value of BMD when evaluating pharmacologic treatment, whereas the main indicator of treatment efficacy is ultimately fracture risk reduction. (Kanis, 2002.)

There are several clinical risk factors for osteoporosis that contribute to fracture risk. They include age, previous fragility fracture, premature menopause, and a few others (Kanis, 2002). On the other hand, there is a host of factors that have their roots in lifestyle – diet, physical inactivity, smoking, dental hygiene, and the like – and in environmental toxicity (Bartolozzi, 2015). These factors will be elaborated briefly in

the next section. The realization of such risks manifests in factures that are associated with significant morbidity, mortality, and cost (Levine, 2006).

3.3 Risk factors of osteoporosis

What are the factors that cause or increase the risk of osteoporosis? Such factors include age, gender, race, lifestyle, and specific medical conditions. Modifiability is one of the primary criteria for classifying risk factors. Various modifiable factors, such as alcohol, smoking, inactive lifestyle, and low levels of calcium and D vitamin, affect the risk of osteoporosis. However, many risk factors are beyond our control, including biological sex, race, age, and body size. (Dontas & Yiannakopoulos, 2007.) A systematic picture of risk factors for osteoporosis are presented in Table 1.

Table 1. Risk factors involved in osteoporosis.

Major modifiable risk factors	**Major non-modifiable risk factors**	**Secondary causes of osteoporosis**
Inadequate nutritional absorption Lack of physical activity or fall risk Weight loss Cigarette smoking Alcohol consumption Air pollution Stress	History of falls Older age Gender White ethnic background Prior fracture Reproductive factors (family history of osteoporosis)	Chronic use of certain medications (prolonged corticosteroid use, and so on) Hypogonadism Hyperparathyroidism Chronic liver disease Inflammatory diseases (rheumatoid arthritis, and so on) Vitamin D deficiency Renal disease (history of kidney stones) Cardiovascular disease Diabetes mellitus Dementia

Source: Pouresmaeili et al., 2018.

An interesting example of an important category among elderly are falls, which are the primary reasons for a large percentage of fractures and one of the major causes of morbidity and even mortality worldwide (Dontas & Yiannakopoulos, 2007). Fall risk itself is a modifiable category, but the history of falls is non-modifiable one, as pointed out in Table 1.

The accurate identification of risk categories is important for the development of effective regimes for the prevention of such risks, and in the case of modifiable risks, for providing sufficient information to people in order to modify their behaviours or at least providing them knowledge that make it possible for them to understand the consequences of their risky actions, such as substance misuse to high-risk behaviours. Let us take an example. Previously mentioned fall risk has been identified as a considerable risk among older adults. This provides direct input in the development of effective regimes for fall prevention. In this case prior research shows that the condition of people with osteoporosis often leads to poor balance control or even falls. This implies that the prevention of falls and fractures depend on the improvement of muscle quality, strengthening of weak muscles, and correcting posture. (Hsu et al., 2014.) This, in turn, indicates how physiotherapy may contribute to the prevention and treatment of osteoporosis.

From the point of view of this thesis, gender and age are of critical importance as non-modifiable risk factors. Women have less bone tissue, and they lose bone more quickly than men because of the menopausal changes, whereas age is vital because bones become thinner and weaker as we age (Seeman, 2002; Corrado et al., 2020). These two factors will be briefly elaborated next.

3.4 Impact of age and sex on osteoporosis

Osteoporosis as the most common bone disease is a serious public health issue. It is seen to be particularly common among Caucasians, women, and older people (Sözen et al., 2017). While osteoporosis affects a huge number of people, including both genders, all ethnic groups and all ages, there are also a few important variables to be highlighted. First, it is more common among women than men. Some 61% of osteoporosis fracture occur in women (Johnell & Kanis 2006). It is a chronic disease affecting one woman out of three, having particularly negative impact on wellbeing of postmenopausal women (Keen & Reddivari, 2023; Sarafrazi et al., 2021).

Second, the prevalence of osteoporosis increase as the population ages. (Sözen et al., 2017; Cosman et al., 2014; Cosman et al., 2017.) This is why middle-aged and older

women are primary target in this thesis. As concluded by Cosman and others (2014, p. 2363), "[t]he rate of bone loss accelerates in women at menopause and continues to progress at a slower pace in older postmenopausal women …". While osteoporosis is a problem with older men too, especially after the age of 70, the prevalence is essentially lower than among women (Cosman et al., 2014). For that reason, older women can be legitimately seen as the most important target group of osteoporosis prevention and treatment.

4 PREVENTION AND TREATMENT OF OSTEOPOROSIS

4.1 Nonpharmacologic treatment regimen

The treatment of osteoporosis is taken into consideration when individuals are assumed to have a high fracture risk (Kanis, 2002). The treatment regimen addressing osteoporosis is generally divided into two major parts, pharmacologic and nonpharmacologic interventions that aim at decreasing the risk of fracture. *Pharmacologic* treatment includes such as the antiresorptive medications (bisphosphonates and denosumab), estrogen therapy, raloxifene designed to prevent and treat osteoporosis in postmenopausal women, salmon calcitonin, and the anabolic therapies (teriparatide and romosozumab). Most of the studies in this field have focused on the effects of anabolic therapies that aim at increasing the bone mass and antiresorptive therapies that focus on decreasing bone resorption (Pouresmaeili et al., 2018). *Nonpharmacologic* management of osteoporosis forms a diverse family of interventions, which includes calcium and vitamin D supplementation, weight-bearing exercise, muscle strengthening, fall prevention, hip protectors, and lifestyle-related interventions. (Levine, 2006.)

There is some evidence and clinical experience to claim that nonpharmacological prevention includes valid treatment options that have a potential to assist patients to avoid the lasting effects of osteoporotic fractures. Such interventions include weight

bearing and strength training exercise, fall prevention, external hip protectors, as well as certain alternative therapies. The latter include a device that enables dynamic motion therapy, chiropractic care, acupuncture, Chinese herbal medicine, and Tai Chi as an exercise intervention. (Kessenich, 2007; Body et al., 2011.)

4.2 Exercise as an intervention

Physical activity is paramount to reaching optimal peak bone mass and increase bone strength. Regarding evidence, there are numerous studies that shown the positive effects of various types of exercise on bone mass. In terms of prevention and treatment, the main objective of physical exercise is to reduce fracture incidence, and in this particular respect, there is a lack of evidence from research. As formulated by the Belgian Bone Club, a nonprofit scientific organization, "no large, well-designed controlled trial assessed, so far, the effect of exercise therapy with fracture as an outcome. As a result, exercise interventions for patients with osteoporosis mainly reported the reduction of risk factor for fracture, i.e. a decrease in the propensity to fall and/or an increase in BMD." (Body et al., 2011, p. 2773). Mobility impairments, such as poor balance and muscle strength, have also been used as outcomes in clinical trials because they are risk factors for falls and fractures. On this basis the Club divides physical activities into two primary target areas, (a) bone mineral density, and (b) risk factors for falls. (Body et al., 2011; cf. Bonner et al., 2003.)

Physical activities have become standard elements in guidelines for the prevention and treatment of osteoporosis (e.g. NIH, 2000; Bonner et al., 2003; Body et al., 2011; LeBoff et al., 2022). According to a systematic review of clinical practice guidelines that aimed at identifying nonpharmacologic recommendations for the treatment of osteoporosis shows that exercise is among the most common recommendations (Coronado-Zarco et al., 2019). The point of departure of such a view is to acknowledge the benefit of physical activities for maximising peak bone mass and maintaining bone strength. It forms the core of a nonpharmacologic intervention for preventing bone loss in the elderly. It is worth emphasizing, however, that such exercise protocols vary considerably by intensity, frequency, duration and mode (Harding & Beck, 2017).

Regarding other dimension of our target group, postmenopausal women, Pouresmaeili and others (2018) conclude that "[b]oth aerobic exercise and resistance training, the best forms of weight-bearing exercise, increase the rate of bone remodelling in postmenopausal women. However, resistance exercise training induces more effective favourable changes in BMD status than aerobic exercise training in postmenopausal women." (Cf. Aldahr, 2012). Such findings are in line with a previous study which concluded that resistance exercise has a significant protective effect on several changes associated with loss of bone mineral density. (Pouresmaeili et al., 2018.) In the same vein, Zehnacker and Bemis-Dougherty (2007) found out in their review that there was evidence to claim that weight training exercises can effectively increase BMD in postmenopausal women.

4.3 The role of physiotherapy

Non-pharmacological intervention (NPI) modalities are widely applied in physiotherapy, including weight-bearing exercise, therapeutic exercise, postural exercise, strengthening exercise, balance exercise, and education (Physiopedia, n.d.). Physiotherapists have a specific role to play in the prevention and management of osteoporosis and rehabilitation through exercise prescription, therapeutic modalities, specific techniques, and education (Bennell et al., 2000).

The relevance of physiotherapy can be seen both directly and indirectly in the current literature as well. For example, Senderovich and others (2017) conclude that exercise is a viable method for combating bone loss and reducing fall rates. Similarly, Benedetti and others (2018) have found out in their review that the two most beneficial forms of exercise for people with osteoporosis are weight-bearing aerobic activities and resistance training (see also LeBoff et al., 2022). They emphasize the potential of multicomponent exercises that combine different methods from aerobics to progressive resistance to balancing to dancing, which is potentially a feasible way of preserving bone mass with elderly people. Additionally, Senderovich and others (2017) suggested that older people should utilize multiple interventions, such as vitamin D supplementation alongside exercise. These observations imply that the contribution of physiotherapy in treating and preventing osteoporosis is achieved

through the improvement of movement, stability, and mobility (Senderovich et al, 2017; Benedetti et al, 2018).

Based on a project that addressed exercise the prevention of osteoporosis in postmenopausal women, Daly and others (2019) assert that exercise training can simultaneously improve multiple skeletal and fall-related risk factors. It has its precondition, however. The intervention must reflect the desired outcomes and be tailored to the specific needs of each target group. According to them, exercise training is an effective way of improving a range of fracture risk factors in postmenopausal women. Even if there have been no optimal training programs available, the current hint of evidence emphasizes the role of multimodal programs, which in turn fall by and large into the expertise areas of physiotherapists (Daly et al., 2019).

5 METHODOLOGY

5.1 Descriptive literature review

Collecting and assessing evidence of the effectiveness of exercise in osteoporosis management is the best way of painting a big picture of the role of exercise and its effectiveness. For this reason, this study relies on literature review. It is commonly seen an appropriate research strategy when the goal is to provide an overview of a specific issue. It can be used when exploring the collective evidence in a particular research area, for example. (Snyder 2019.) Its basic idea is to use database searches in the purpose of retrieving the results of research. This thesis collects evidence-based knowledge of prevention and treatment of osteoporosis, thus relying primarily on existing scientific literature.

There are various forms of literature review, including systematic, semi-systematic, integrative, narrative, descriptive, mapping, scoping, and critical reviews (Pare et al.,

2015), which poses a challenge of choosing the right type of literature review in the light of the research problem of this thesis.

After the review of different approaches to conducting literature review, the most appropriate for this thesis among them appeared to be a slightly modified version of descriptive literature review (Yang & Tate 2012; Templier & Paré, 2015). It fits well with the research that aims at providing an overall view of the current state of research on the topic of this thesis.

In essence, a descriptive literature review provides a summary of existing research, which is treated in a descriptive, yet comprehensive manner. Regarding the process, there are a few slightly different versions of it. The simplest one is based on a description of the relevant literature as a part of research process (Coughlan et al., 2013). Even in such a case certain methodological requirements must be met, however. These include the research question, proper data collection, and systematic analysis. As an example of simple descriptive review, we may mention Boers and others' (2013) article 'The Application of Dynamic Assessment in People Communicating at a Prelinguistic Level: A descriptive review of the literature'. Another methodologically rudimentary literature review is Bhatnagar and Kekatpure's (2022) article 'Postmenopausal Osteoporosis: Literature Review', in which evidence of the effectiveness of treatment is mentioned in endnotes based on authors' non-systematic review of literature. Usually, descriptive literature reviews are more systematic and methodic than these kinds of simple reviews, and this thesis follows such a methodic approach, which takes it closer to systematic review.

Methodologically descriptive literature review is located somewhere between qualitative and quantitative reviews. In its conventional form it aims to identify interpretable patterns from existing literature. (Schlagenhaufer & Amberg, 2015.) Quantitative information can be about publication time, research methodology, and research outcomes. The results of descriptive review are expected to be representative of the current state of the research area. (Yang & Tate, 2012.) Such reviews offer typically information about individual studies and their methods and outcomes, which explains their tendency to pay special attention to research method, evaluation, and

results (Jaidka et al., 2013). This is important point, because in this review the focus is on special aspects highlighted by each article, on the one hand, and the overall view of the level and nature of evidence they provide as a whole, on the other.

5.2 Review process

Descriptive literature review is conducted by following conventional steps of the review process, which enables systematic data collection, filtering, and analysis. It utilizes structured search methods in the purpose of forming a representative sample of a larger group of published works. (Popenoe et al., 2021; Templier & Paré, 2015.) It contains fairly similar phases as systematic literature review. However, the latter is usually done by a review team and its process is rigorous and methodical. Descriptive review, on the other hand, places more emphasis on the descriptions of the reviewed articles according to the given criteria. It is important to note that the classification phase that is sometimes included in descriptive reviews, is omitted here as it does not have relevance from the point of view of the research problem of this thesis. Rather than classification of the forms of exercise based on the wider dataset, the focus in this thesis is on distilled knowledge of evidence of the effectiveness of exercise in osteoporosis prevention and treatment based on a fairly narrow selection of most relevant journal articles. The idea is to extract from each study specific characteristics of interest to produce results that are then described and interpreted in the analysis (Templier & Paré, 2015).

There are six general steps to be taken in literature review (Templier & Paré, 2015):

1. formulate the research question(s) and objective(s),
2. search the extant literature,
3. screen for inclusion,
4. assess the quality of primary studies,
5. extract data, and
6. analyze data.

In literature reviews special attention is paid to data collection and, as a part of it, the use of databases and possibly other relevant resources. Another critical phase is to determine inclusion and exclusion criteria in order to select most relevant articles for the review. In the extraction phase focus is on extracting applicable data from each primary study included in the sample, followed by an assessment of what data is relevant to the research. The process ends up with analyzing the data and writing the review. (Paré & Kitsiou, 2017; Templier & Paré, 2015.)

5.3 Data collection and filtering

In this thesis, data selection and filtering were divided into two phases. The first phase relies on the idea of translating research problem into relevant keywords and utilizing them systematically in the search of relevant literature. The terms used in this search matched with MeSH (Medical Subject Heading), which is the National Library of Medicine's controlled hierarchical vocabulary (Grewal et al., 2016). In the first phase the search was made by using FINNA search service, which uses such databases as PubMed, Science direct, EBSCO, Emerald, SAGE, and a few others. The search was done by using Boolean operator 'AND' to combine osteoporosis, exercise*, and bone densit* covering the years 2015-2022. This was the initial identification and screening operation. The set of potential articles was narrowed down with a fourth keyword, prevent*, and again in the third round with another keyword, middle-aged. In the last round these were further narrowed by the category of women, using three terms (woman OR women OR female). This procedure produced 32 relevant articles, as shown in Figure 1. It is worth reminding that the first verification process could utilize also titles of the article and abstracts, but in this case, filtering was based completely on keywords. The keyword-based filtering is supplemented by inclusion and exclusion criteria, which are used to determine which articles in the larger pool are included in the final review. Such criteria are collected in Table 2.

Table 2. Applied inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
Exercise as an intervention	Exercise intervention not clearly defined

BMD as measurement outcome	No BMD measurement as outcome
Designed for women, preferably aged women with or without bone loss	Designed for men only
Publication year between 2015-2022	Publication year before 2015
Peer reviewed	Not peer reviewed
The language of publication is English	Written in other language than English

In the second phase, the search elimination was based in the screening of abstracts. The pool of articles was further narrowed down by filtering, in which ‘exercise as an intervention’ was used as an inclusion criterium, which resulted in the inclusion of 13 and elimination of 19 articles. In order to guarantee high degree of relevance in terms of measurements, those articles were eliminated that did not apply BMD measurement as an outcome. This left altogether 9 articles for the review, in which the keyword combination is directly related to the research problem of this thesis. These articles discuss the exercise as an intervention to improve bone health related to osteoporosis in middle-aged women by measuring BMD as one of the outcomes. This procedure is illustrated in Figure 1.

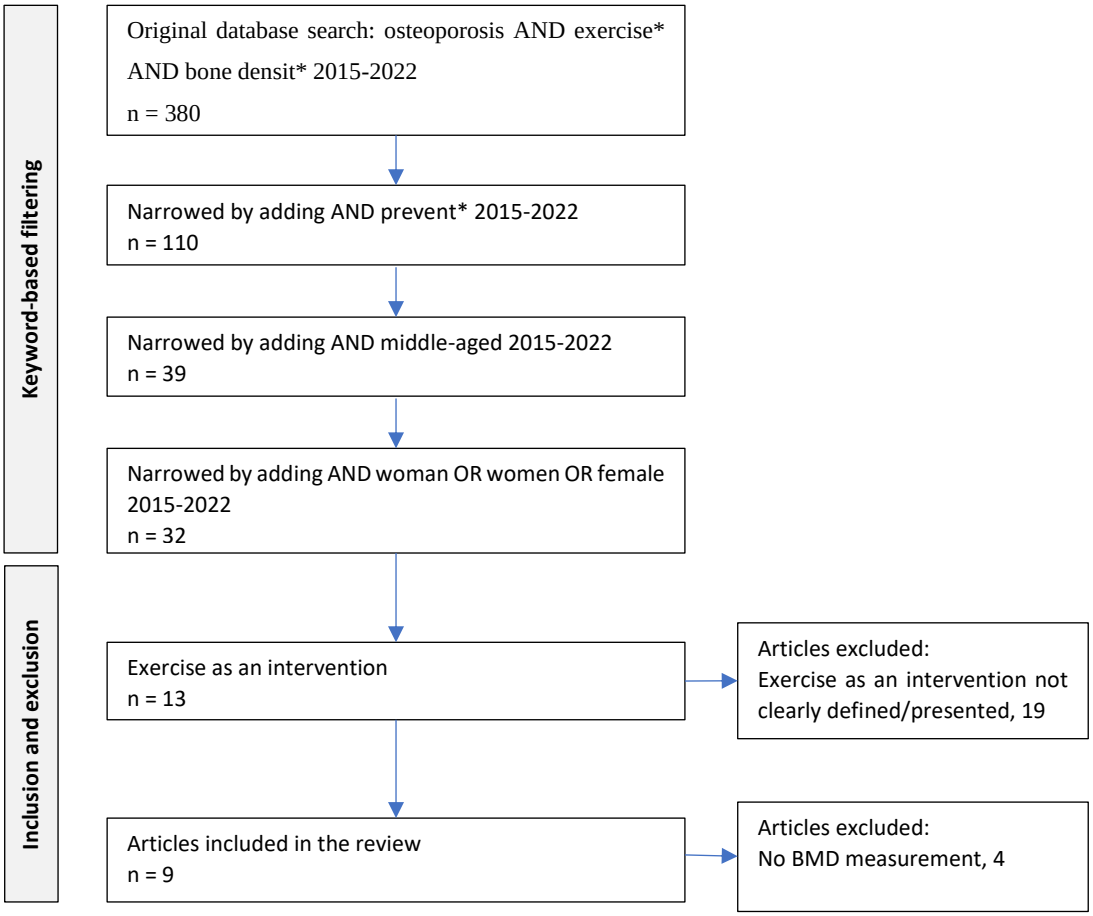

Figure 1. Data selection and filtering procedure

5.4 Data analysis

Data collection and filtering have produced relevant data to be analyzed utilizing categorizations that reflect the research problem. As the generic research problem does not determine the structure of analysis *per se*, it must be decided either deductively or inductively, the former relying on pre-existing theories or categorizations and the latter on ideas and insights drawn from the nature of data. As in this thesis the sought evidence concerns different forms of exercise, they form the starting point of the qualitative content analysis.

The methodological preconditions and methodical needs of descriptive literature review in creating systematic content from the selected articles leans naturally towards qualitative methodology and inductive logic (Graneheim & Lundman, 2004; Elo &

Kyngäs, 2008). On the basis of the assessment of different methodological options, the qualitative content analysis was deemed most suitable method for this descriptive literature review. As there are no comprehensive previous studies on which the discussion about the evidence of the efficacy of exercise on improving bone density particularly for over middle-aged women with low bone mass could be based on, it is feasible to rely on inductive logic in content analysis (Elo & Kyngäs, 2008).

The qualitative content analysis is based on coding that reflects and operationalizes the aims of the research. Through systematic data-driven coding, content elements found from the data are identified and named. The units of analysis are primarily words, though they must be interpreted in each given context. As the focus in this analysis is on manifest content, it gives the analysis a strong descriptive flavor (Graneheim et al., 2017). After the text is coded, analysis continues with forming larger categories from the codes, which are recategorized, which helps to build a picture of how the primary categories are broken down into inductively identified pieces of information. (Graneheim & Lundman, 2004; Elo & Kyngäs, 2008.) The result of the coding of conceptual categories is presented at the beginning of Results section (see Table 3). These categories inform both the structure and core categories of the analysis.

The analysis that follows the coding phase is conducted following the data analysis methods described by Graneheim and Lundman (2004), Elo and Kyngäs (2008), and Popenoe and others (2021). Due to the inductive logic of coding and content analysis, content is created from the data without binding pre-existing framework, i.e. data lead to hints of the conceptions and patterns that can be identified as answers to a research problem (Popenoe et al., 2021; see Vaismoradi et al., 2013). In this case the ultimate aim is thus to seek patterns that relate to the evidence of the efficacy of exercise in treating or preventing osteoporosis in middle-aged women.

6 RESULT

A total of nine studies were selected in this thesis for the review. All of them present some form of exercise as an intervention. Author divided the forms of exercise into two major categories: high-intensity exercise and low to moderate intensity exercise. This division is based on the indication that the intensity of exercise relates to the efficacy of exercise. This connection is elaborated later in this chapter.

Each article described the intervention that included BMD measurement as one of the outcomes. Some of them measure only BMD, while others include multiple outcome categories. The primary categories form the main content of this paper, reflecting the previously mentioned dichotomy of intensity of exercise, while the subcategories show how the higher-level (secondary and primary) categories are formed as results, and equally importantly, enable diving deeper into the nuanced aspects of the efficacy of exercise. The result of the initial coding is presented in Table 3.

Table 3. Conceptual categories analysed in this thesis.

Subcategories	Secondary categories	Primary categories
BMD (LS, Hip, FN)	Bone health	High-intensity exercise
Markers of bone turnover		
Bone structure		
Preventing falls	Falls	
Fear of falling		
Functional performance		
Muscle strength	Physical fitness	
Cardiometabolic greed		
Lean body mass		
BMD (LS, Hip, FN, whole body)	Bone health	Low to moderate intensity exercise
Markers of bone turnover		
Serum Cal/Phosphorus		
Preventing falls	Falls	
Fear of falling		
Functional performance		
Muscle strength	Physical fitness	
Gait-speed		
Balance		

Results of content analysis are discussed in detail the next chapter.

6.1 High intensity exercise

Three out of nine articles fall into the primary category of high-intensity exercise (Watson et al., 2018; Hettchen et al., 2021; Waltman et al., 2022). The exercise programs of these interventions are high-intensity resistance and impact training, high-intensity and bone-loading exercises and, on top of this, all of them base their evidence on Randomized Controlled Trials (RCTs). First, high-intensity resistance and impact

training (HiRIT) is a combination of resistance exercise such as deadlift, overhead press, and back squat with impact loading such as jumping with overhead bar. Such exercise program was supervised for 8 months twice per week for 30 minutes (Watson et al., 2018). Second, high-intensity exercise program consisted of weight-bearing exercise via aerobic dance and jumping as well as five phases of resistance exercise. It was conducted by supervisor 13 months, three times per week for some 40 to 50 minutes at a time (Hettchen et al., 2021). Lastly, bone loading exercise program was conducted for 12 months three times per week. It had two parts: high-impact weight-bearing exercises and resistance exercises. Weight-bearing exercises mainly involved jogging using a weighted vest, and resistance exercises progressed up to 70-85% of 1 RM (1RM was tested) (Waltman et al., 2022). All studies were particularly designed for the postmenopausal women with low bone mass, which can be either osteopenia or osteoporosis.

6.1.1 Bone health

Results of bone health in this paper looked at bone mineral density, marker of bone turnover and bone structure (Watson et al., 2018; Hettchen et al., 2021; Waltman et al., 2022). All three articles referred to above measured BMD using DXA scans and reported BMD as a primary outcome. All three articles reported BMD score on lumbar spine, two studies included also hip and femoral neck. Two studies, those by Watson et al (2018) and Hettchen et al (2021), showed significantly increased BMD at lumbar spine, while the study by Watson et al (2018) found in addition an increase in BMD at femoral neck after exercise intervention. However, none of studies showed any changes BMD outcomes on hip. Regarding biomarkers of bone turnover and bone structure, Waltman et al (2022) stated that there were no differences in serum biomarkers of decreased bone formation and resorption in the exercise group. Lastly, Watson and others (2018) found out that the effect on femoral neck thickness and height within exercise group was superior to control group after 8-month intervention.

6.1.2 Falls

The category of falls includes fall prevention, fear of fallings, and physical performance (Watson et al., 2018). Typically, falls prevention exercise programs include balance and functional and resistance training, which may have an impact on reducing in falling that result in fracture (El-Khoury et al., 2013). Previously, functional performance such as five times sit-to-stand, timed up-and-go test, and functional reach scores have been shown to be associated with balance and incident falls (Farinatti et al, 2013; Sousa et al., 2005). Watson et al. (2018) observed that their exercise program improved all functional performance scores. They stated that their exercise program may reduce fracture risk by enhancing bone strength and by preventing falls (Watson et al., 2018).

6.1.3 Physical fitness

Among three articles, Hettchen and others (2021) was the only one that reported on physical fitness relating to muscle strength, cardiometabolic speed, and lean body mass. Thirteen months of high-intensity exercise significantly effected in favor of exercise group lean body mass and muscle strength in lower limb but not for MetS-Z score on cardiometabolic speed (Hettchen et at., 2021).

6.2 Low to moderate intensity exercises

All remaining six articles fall into the category of low to moderate intensity exercise. The exercise programs of these studies are brisk walking, tai chi, two jumping, whole body vibration, mini-trampoline, and aerobic and resistance training (Lan et al., 2022; Zhang et al., 2019; Tucker et al., 2015; Jepsen et al., 2017; Posh et al., 2019; Dieli-Conwright et al., 2018). The first of these, Lan et al. (2022), discussed a survey in healthy premenopausal women, focusing on their physical activity level categorized into the brisk walking group and sedentary group. Then, the study recruited sedentary women to conduct brisk walking program organized as a cohort study, and verbally advised to perform weekly brisk walking combined with a moderate intensity level of

physical activity. After two years, they were dived into five groups based on activity level for outcome measurement. (Lan et al., 2022.)

In the second study Zhang and others (2019) provided meta-analysis of the efficacy of Tai Chi (TC) as an adjuvant treatment for osteopenia or osteoporosis. They collected 15 RCT (N=857) articles for the review. The study paid attention to the TC exercise for regulating the bone mass. All their participants were with osteopenia or osteoporosis and the duration of trials ranged from 4 to 12 months. They divided the groups of TC into subgroups in order to compare the outcomes with other control groups without treatment or with conventional treatment. (Zhang et al., 2019.)

In third article, Tucker et al (2015) discuss RCT to evaluate the effects of two jumping programmes. Randomly selected participants were assigned to two jumping groups, those of the jump 10 group and the jump 20 group. The trial was conducted on thick carpet without socks and shoes, as participants were asked to jump as high as they could 10 times or 20 times with 30 seconds rest between the jumps. This was carried out twice a day and six days a week for 16 weeks. (Tucker et al., 2015.)

The fourth article, Jepsen et al. (2017), is a systematic review and meta-analysis of 14 RCTs examining the effect of whole-body vibration (WBV) on different parts of the body compared with a control group. In all 14 trials were performed in standing position on various vibration devices. Each study was conducted with different training frequencies and times per week and had a duration of 6 months to 24 months. (Jepsen et al., 2017.)

The fifth article, Posh and others (2019) used a randomized controlled study design to evaluate the effectiveness of Mini-Trampoline training on postmenopausal women with low bone mass. Their study includes balance exercise, strength exercise, and jumping. It was conducted on Mini-Trampoline exercise twice a week for 12 weeks with 45-60 mins duration of each session. The program had three phases: learning, improving, and maintaining. (Posh et al., 2019.)

Lastly, Dieli-Conwright et al. (2018), studies effectiveness of aerobic and resistance exercise on obese breast cancer survivors. The exercise consisted of treadmill walking and running, rowing, stationary bicycle as an aerobic exercise, and the resistance exercise with circuit training with eight different stations. The exercise program was conducted three times a week with 50-80 mins duration for 16 weeks. (Dieli-Conwright et al., 2018.)

6.2.1 Bone health

All studies discussed in this category also measured BMD using DXA scans and five out of six studies reported BMD as a primary outcome. Five studies reported data at lumbar spine, four studies at femoral neck, three studies at hip, two studies on whole body, and one study at forearm.

As results of level of BMD, Zhang et al. (2019) with their meta-analysis with 15 trials found significant difference outcomes on BMD level at lumbar spine, femur, and forearm compared to control group with conventional care without exercise. In their study Tucker et al (2015) concluded that Two Jumping programs (Jumping 10 times and the Jumping 20 times) improved greatly hip BMD in premenopausal women after 16 weeks intervention compared with a control group. While Posch and others (2019) did not find the significant improvement by Mini-Trampoline exercise in BMD by 12 weeks intervention period, there was slightly increased BMD on femoral neck after the intervention. Zhang and others (2019) also found out that one of the biomarkers of bone turnover, bone gla protein (BGP), also called osteocalcin, was significantly different after exercise intervention. However, they did not detect serum calcium and phosphorus, which are essential in bone metabolism.

6.2.2 Falls

Two articles reported data regarding falls. Jepsen and others (2017) reported fracture and fall rate as primary outcomes. In their meta-analysis they found whole-body vibration has moderate quality of evidences (using GRADE guidelines) on significant

reductions of fracture and rate of falls. Posch and others (2019) reported data on fear of falls using Falls Efficacy Scale (FES) and static balance by one-leg stance which related to falls. Both test parameters showed significant interactions in exercise group (Posh et al., 2019).

6.2.3 Physical fitness

Two articles reported data on muscle strength, gait-speed, and functional mobility in physical fitness. Dieli and others (2018) and Posch and others (2019) presented upper and lower limb strength test. Both found significant improvements in muscle strength in the exercise group. Posch and others (2019) also found than exercise improved all test parameters of gait-speed (6m walking test) and functional mobility (timed up and go test).

6.3 Evidence of the usefulness of exercise

To sum up, this descriptive literature review shows that there is evidence of the effectiveness of certain kinds of exercise in preventing and treating osteoporosis in middle-aged women. However, there are certain forms of exercise, which are not supported by empirical evidence. In this respect, the result of evidence is mixed, and require thus further elaboration. The articles reviewed in this literature review are mentioned in Table 4. Besides the identification of each article, the table includes the form of exercise intervention, sample size, duration of trial, and outcomes in terms of BMD.

Table 4. Overview of the analysed articles.

Author(s), publication year	**Exercise**	**Design & types of participants**	**Sample size (CG/EG)**	**Duration of trial**	**Outcomes**
Waltman et al 2022	Bone loading exercise	RCT Postmenopausal osteopenia	CG:82 EG:82 RG:82	12 months (follow up: 5 years, only EG)	BMD No changes

Dieli-Conwright et al. 2018	Aerobic and resistance exercise	RCT Breast cancer survivor	CG:50/45 EG:50/46	16 weeks (follow-up: 3 months, only EG)	BMD No changes
Jepsen et al. 2017	Whole-body vibration	Systematic review & meta-analysis	15 RCT (N=1,839)	6-24 months	BMD No changes
Tucker et al. 2015	Jumping	RCT Premenopausal women	CG:23 EG1:23 EG2:20	16 weeks	BMD Effect on hip
Hettchen et al. 2021	High-intensity exercise	RCT Postmenopausal osteopenia	CG:27 EG:27	13months (Origin 18mons, stopped due to covid)	BMD Great effect on L-spine
Watson et al. 2018	HiRIT	RCT Postmenopausal osteopenia & osteoporosis	CG:52/43 EG:49/43	8 months	BMD Great Effect on L-spine & hip
Zhang et al. 2019	Tai Chi	Meta-analysis Osteopenia & primary osteoporosis	15 RCT (N=857)	4 – 12 months	BMD effect
Lan et al. 2022	Brisk walking	Cohort study Premenopausal women	CG:10 EG1:4 EG2:7 EG3:8 EG4:6	2 years	BMD Increased value
Posch et al. 2019	Mini trampoline	RCT Older women with osteopenia	CG:21/20 EG:22/20	12 weeks	BMD No changes

CG = Control Group; EG = Exercise Group (or Experimental Group); RG=Risedronate Group; RCT = Randomised Controlled Trial; BMD = Bone Mineral Density; HiRIT = High-intensity Resistance and Impact Training

The evidence shows that regarding BMD results, there is a clear difference between high intensity exercise and low to moderate intensity exercise. We may also distill from the data two patterns, intensity and duration, that affect the result of exercise intervention and, interestingly, affected bone health. These results will be explained and elaborated in the Discussion section.

6.4 The nature and level of evidence

When considering one of the fundamental indicators related to osteoporosis, bone mineral density (BMD), exercise interventions showed mixed results. Four reviewed articles – Dieli-Conwright and others (2018) discussed about aerobic and resistance exercise, Waltman and others (2022) about bone loading exercise, Jepsen and others

(2017) on whole-body vibration (WBV), and Posh and others (2019) on balance, strength and jumping exercises using mini trampoline – showed that intervention did not make significant changes to BMD. While the remaining five articles showed that exercise produced some benefits in terms of the level of BMD, which can be seen as a significant result. This may be affected by the nature of exercise as well as the duration of the trials or some similar reasons.

As pointed out by Posh and others (2019), it appears to be hard to draw a definitive conclusion on the efficacy of the training intervention on BMD if the duration of the intervention is short. This implies the need for longer intervention times and a careful assessment of the type and practical aspects of exercise, as the latter is decisive in determining the level of impact. As the increase in BMD levels may be more difficult to achieve than other results, such as improving balance and functional mobility, strength, and gait performance, as well as decreasing the fear of falling (Posh et al., 2019). This viewpoint has a relationship with the pattern found from the data, which will be elaborated in the next section.

7 DISCUSSION

This descriptive literature review provides evidence of the efficacy of exercise for the prevention and treatment of osteoporosis. Discussion is based on nine carefully selected articles. When reviewing the data, the author detected two patterns that affect the result of exercise intervention. They revolve around the categories of ‘intensity’ and ‘duration’.

These two patterns have a direct connection with bone health. When it comes to BMD results, there is a clear difference between high intensity exercise and low to moderate intensity exercise. Even though the participants of high intensity exercise were all postmenopausal women with low bone mass, the high-intensity exercise had a higher effect on BMD levels for each measure on different body parts compared with the low intensity exercise, which was mostly performed in adult women without bone loss. This appears to result in the fact that the intensity of exercise is the key to improving

bone density. Among high intensity exercise, most efficient exercise was HiRIT studied by Watson et al. (2018). While Watson and others (2018) stated that there have been no methodologically adequate trials in terms of size and duration to determine the efficacy of high intensity loading to improve bone mass in postmenopausal women with osteopenia or osteoporosis, they nevertheless observed improvements in BMD of their trial. They concluded that the level of BMD surpassed the findings associated with previous reports that discussed exercise interventions that were considered reputable. All the BMD outcomes were significantly increased. It was a novel discovery. (Watson et al., 2018.)

Another conclusion of the study of Watson et al. (2018) was that there is a good reason to challenge the limits of high intensity and resistance training, Namely, traditionally such training is not recommended for individuals with low to very low bone mass due to the increased risk of fractures in fragile bones subjected to heavy loads. Contrary to such common opinion, evidence of this study found that high intensity exercise was effective and induced no adverse events. Thus, the tentative guideline drawn from the data is that high-intensity loading can be recommended to postmenopausal women with osteopenia or osteoporosis. (Watson et at., 2018.)

In addition, low to moderate exercise has also positive results in terms of bone health. Tai Chi (TC) intervention studied by Zhang et al. (2019) increased all BMD measurement of LS, hip, femoral neck, and forearm. Their finding is most relevant in the low to moderate exercise category in terms of bone health. They also found significant difference in biomarker of bone turnover, which implies that TC may slower down the process of bone loss in menopausal women. (Zhang et al., 2019.)

Regarding duration, the longer intervention period (>12 month), the better results especially regarding the improvement of BMD level. The results were seen both in high-intensity and low-intensity exercises. For example, in the two-year intervention study by Lan and others (2022), which was the longest intervention time among the selected articles, significant results in improving BMD were found even with fairly low intensity exercise, such as brisk walking. The only exception in this respect is two jumping studied by Tucker et al. (2015). They found great gains on hip BMD with 16

weeks, which was relatively short period of time. In any case, the point to be made here is that their study was conducted only with premenopausal women who had not lost their bone mass. If they applied the same programs with same duration to postmenopausal women with low to very low bone mass, their result could be differed. This is a matter that calls for further research.

It is notable that Jepsen and others (2017) found out that doing Mini-Trampoline for 12 weeks did not improve BMD level significantly. However, despite the short duration of the intervention, it nevertheless improved the BMD level slightly, which has a special significance against the fact that the control group lost BMD level during the same intervention period. That is why they suggested that future research should address potential effects on BMD with longer intervention period. According to Vondracek and others (2009), premenopausal women lost approximately <1% of BMD per year, which concerns particularly individuals with high risk of low bone mass. Therefore, main goal of intervention strategies should aim at maintaining or reducing age-related loss of BMD (Kohrt et al, 2004).

In the study of Hettchen and others (2021), the original duration of intervention was 18 months, which was interrupted, however. They tailored exercise program with multipurpose exercise based on international recommendation aimed to determine the effect of exercise on particularly menopausal risk factors and complaints in early postmenopausal women with low bone density. As a clinical trial this was actually very interesting from the point of view of this thesis. Unfortunately, it stopped after 13 months due to the outbreak of COVID-19. Despite the well-designed exercise protocol of their study, BMD at hip showed no change as a result of intervention, while another study by Watson and others (2018) with similar exercise program produced much higher effect on the BMD level. (Hettchen et al., 2021.) It is justified to hypothesize that this happened because the study in question suffered from time-related deficiency. Therefore, if completed according to the original time frame, their exercise protocol might have contributed to different results, especially on BMD.

Regarding the falls and physical fitness, all the studies showed positive results when measured as outcomes regardless of the exercise intensity and duration. This warrants

a view that intensity-duration pattern is not as relevant with falls and fitness as it is in the case of bone health discussed earlier.

To sum up, improving bone health requires a longer time to reach a bone adaptation threshold that results in a full amount of mineralized bone, which is based on the presumption that bone adaptation in adults is primarily triggered by remodeling. That was the evidence that this thesis started to seek at the outset, and which served as the starting point for the formulation of the research problem.

Lastly, regarding the evidence of efficacy of exercise, it is primarily based on RCTs. The levels of evidence involved in our set of articles vary from two systematic reviews (Level 1), six well-designed RCTs (Level 2), and one cohort study (Level 4), which as a whole provide a basis for fairly strong evidence. (On the levels of evidence applied here, see Melnyk et al., 2011.) There is a high level of evidence available on the efficacy of exercise in preventing and treating osteoporosis based on systematic reviews or meta-analyses of relevant RCTs, even though the categories of exercise in these studies are usually significantly limited. It is worth mentioning that the article by Zhang and others (2019) and Jepsen and others (2017) were meta-analyses. Both studies had positive results for their primary outcomes of BMD and falls. Yet, Zhang and others (2019) suffered from methodological problems, thus providing insufficient evidence of the benefits of Tai Chi. In terms of evidence, the systematic review and meta-analysis conducted by Jepsen and others (2017) provides the highest level of evidence among the articles analyzed here. However, their result did not show the significant impact of exercise on BMD. Besides, both studies reported performance bias due to small sample size and due to participants not being blinded to the intervention. Moreover, even if evidence level of meta-analysis in general is high compared to RCTs or cohort studies, in this case they reported that the quality of evidence was low to moderate by using GRADE guidelines of their studies, which underlines the need for further research with sufficient level of evidence.

Based on nine studies, this review provides evidence of the effectiveness of exercise in the management of osteoporosis in middle-aged women. Author found out that certain exercises have positive effect on BMD score even with postmenopausal women

with bone loss supplemented by many other positive outcomes. These are highly relevant findings. However, this study had some limitations, such as not including articles written in other languages than English and not extracting data from articles published before 2015. Methodological choices bring with them also a few inherent limitations regarding, for example, the number of selected articles, filtering, inclusion/exclusion criteria, and qualitative data analysis.

The reliability of this thesis is primarily guaranteed by following systematically the research methods designed for literature reviews (on reliability in literature review, see Chetwynd, 2022). This concerns especially the use of filtering and inclusion/exclusion criteria in article selection process. Regarding data analysis, reliability was guaranteed by explicating and applying systematically the data analysis strategy and method. This was done by being careful and systematic with coding, being transparent with the choice of key categories of analysis and being transparent about how the content analysis was conducted. It is notable in this respect that in this thesis content analysis was confined to manifest content (see e.g. Potter & Levine-Donnerstein, 1999).

In terms of future research, there is a need for well-designed longer term RCTs, which will improve chances to assess the evidence of the efficacy of exercise. As regards my experience as the author of this thesis, this was an exciting process especially at the time of data collection and analysis, which started to build a picture of the nature of evidence of various forms of exercise. While writing this thesis, Author have learned a lot about the knowledge processes that form the foundation of physiotherapy. As a learning by doing exercise, beside the application of literature review as a research methodology, this thesis writing process has helped me to understand the systematic production of relevant professional knowledge and the utilization of the results of scientific inquiry. This all is an essential in building evidence-based practice in physiotherapy.

8 CONCLUSION

In this thesis I have sought answer to the question of evidence of the efficacy of exercise in middle-aged women. This highlights the setting in which the increase in bone mineral density is discussed regarding individuals with low bone mass or those who started to lose bone density due to osteopenia or osteoporosis. The patterns identified in this analysis suggest that the longer period and the higher intensity exercise have a higher probability to produce positive results. Well-designed and tailored exercise program could be applied to postmenopausal women even if they have started to experience bone loss. The analysis justifies a conclusion that postmenopausal women with osteopenia or osteoporosis should be encouraged to conduct exercise, even tailored high-intensity exercise under professional guidance and supervision.

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