Bachelor's thesis

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Norwegian University of Science and Technology
Faculty of Medicine and Health Sciences
Department of Neuromedicine and Movement Science

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Physical activity on bone health in young to middle-aged women

Bachelor's thesis in Human Movement Science
Supervisor: Xiao-Mei Mai
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Abstract

Purpose: Approximately every other woman will be affected by osteoporosis-related issues at least once in their life. This literature study will therefore investigate if physical activity prior to perimenopause can have a positive effect on bone health in women. In addition, physical activity can help to prevent and/or delay the development of osteoporosis in women.

Method: The studies were found by using the website PubMed up until March 25th, 2022. and by the use of inclusion and exclusion criteria, 8 studies were included in this literature study.

Results: Results from the original articles show that physical activity has a positive effect on the female bone mass density and can be considered a positive factor in preventing osteoporosis with the increase of age.

Conclusion: Physical activity contributes to improving and preserving the bone mass density in women, which appears to be an important factor in the prevention of bone fractures and osteoporosis later in life.

Keywords: premenopausal osteoporosis, physical activity, menopause, climacteric period, bone mass density

Abstrakt

Bakgrunn: Omtrent halvparten av alle kvinner vil rammes av osteoporoserelaterte plager minst én gang i løpet av livet. Denne litteraturstudien tar derfor for seg om fysisk aktivitet før perimenopause kan ha en positiv effekt på beinhelse hos kvinner. I tillegg til om fysisk aktivitet kan bidra til å forhindre og/eller forsinke utviklingen av osteoporose hos kvinner.

Metode: Studiene ble funnet i via databasen PubMed til og med 25 mars 2022. Ved bruk av inklusjons- og eksklusjonskriterier ble 8 studier inkludert i denne litteraturstudien.

Resultat: Resultatene i original artiklene viser at fysisk aktivitet positivt påvirker kvinners benmasse og kan vurderes å være en positiv faktor for forebygging av osteoporose med den økende alderen.

Konklusjon: Fysisk aktivitet bidrar til å forbedre og opprettholde bentetthet hos kvinner, og kan derfor se ut til å være en viktig faktor i forebygging av benbrudd og osteoporose i senere liv.

Nøkkelord: premenopausal osteoporose, fysisk aktivitet, overgangsalder, menopause, beinmasse

Introduction

Osteoporosis has become a rapidly growing health concern across the globe, especially in the Western world (1). Osteoporotic fractures are most common in the hips, spine, and wrists, alongside other osteoporosis-related injuries this has enormous health and economic implications both with a direct and indirect link (2, 3). Generally, osteoporosis occurs in both genders, where women are normally affected at a higher rate when compared to men. Due to women having a higher relative loss of bone mass density (BMD), especially around the menopausal age. During menopause women have a large reduction in their BMD, which can lead to women having a significantly smaller BMD compared to men as they age (4 - 6). As a result of the decreased BMD women are at a greater risk of developing fragile bones and osteoporosis, which can lead to a greater risk of osteoporotic fractures.

Perimenopause is the time period in a woman's life where the ovarian function progressively decreases. This results in a gradual change within the female body, and this is the time where they go from regular periods until they no longer have them. Normally women are peri-menopausal around the age of 45-50 years, and for most women, they will be peri-menopausal for approximately 5 years. Menopause is the last menstrual period for a woman, and this normally occurs around the age of 45-55 years, where the average woman has their last period at 52 (5, 7). Premenopause will therefore be the time period before perimenopause including adolescence and the middle-aged woman. The terms premenopause and young to middle-aged will in this paper will be used interchangeably.

Peak bone mass is achieved around the mid 20's, after which their bone mass slowly begins to decrease with age. There is however not a total agreement on this amongst the different sources. Some say peak bone mass is achieved as early as around 18 years whereas others say early 30's. However, on a general basis, most say around mid 20's (6, 8, 9). The definition of peak bone mass is defined in Aktivitetshåndboken as "*The highest bone mineral density in one's life*" (9). Bone mass is the mineral density (mainly calcium and phosphorus) or the mineral content of the bones within the body (6). Osteoporosis is defined as a skeletal disease and is characterized by a low BMD and microstructural impairments causing the bones to become weaker and increasing the risk of fractures. What happens is that there is a reduction in the mass within the bone, leading to the structure and density of the bones becoming less compact and therefore more fragile. The bones do therefore not change in size, it is the contents within

the bones that change and further weaken them. The physical changes during and after menopause are likely the result of the decreased production of the hormone estrogen. Estrogen is an important component for the stimulation of new bone mass in women. The women who transition into perimenopause earlier than average, are at an even greater risk for developing fragile bones when compared to women who are peri-menopausal around 45-50 years. As a result of reduced production of estrogen, the bone tissue gradually loses its strength. This is because BMD accounts for the majority of the strength in the bones (10, 11).

Genetics, aging, lifestyle choices, hormones, nutrition, diseases, and physical activity (PA) are some of the components that affect a person's bone mass (6, 7). By optimizing the components that we can affect, such as PA we are able to improve and/or preserve the general skeletal health to a certain level (6, 12). The human body is made to be physically active and being active has been shown to significantly improve the quality of life, reduce the risk of disease, injuries and premature death (13). The effects of PA can both have short and long-term results. PA is defined as all bodily movements due to the activation of muscles, which will lead to the total energy consumption to increase (14).

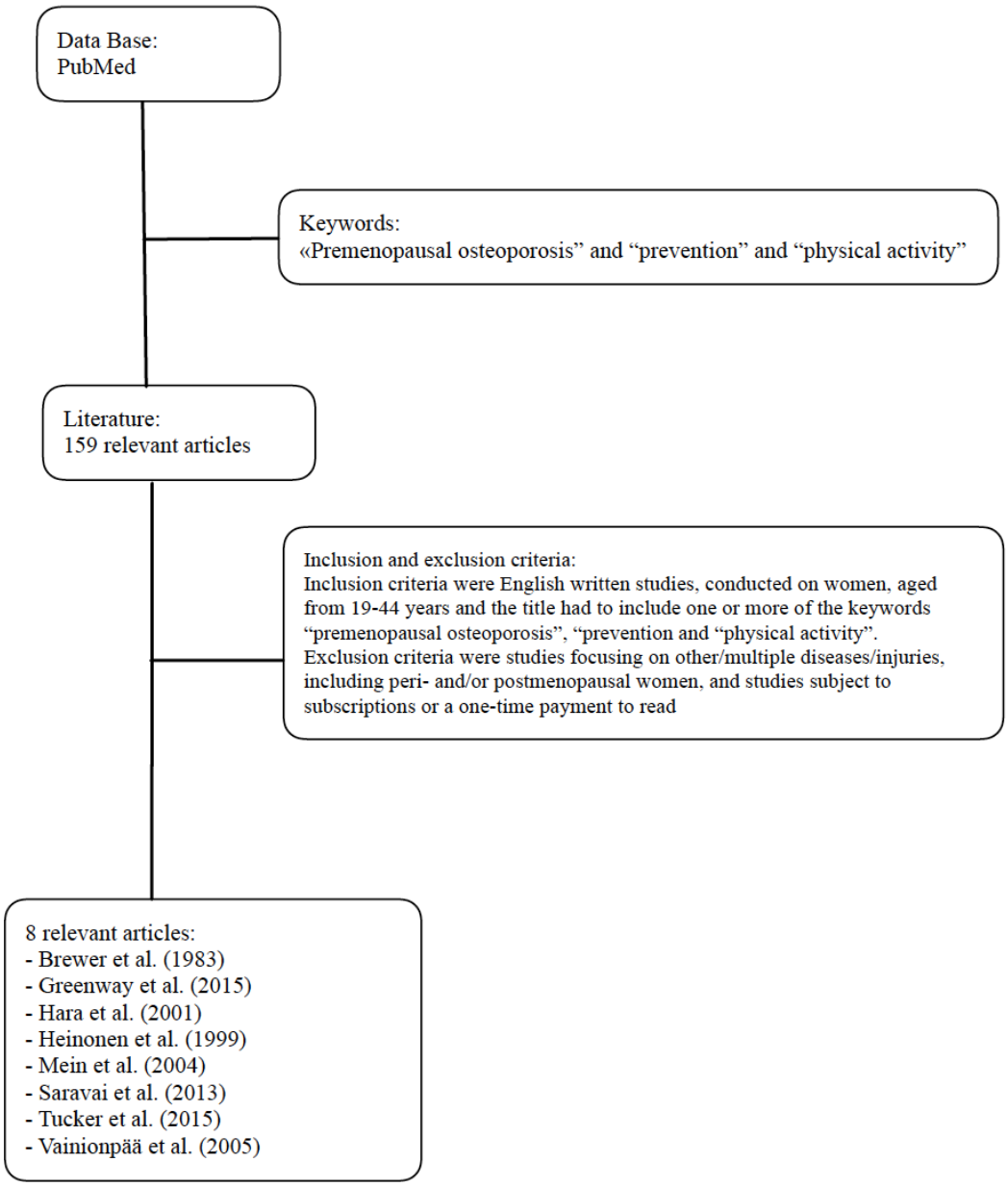
Approximately 50% of women will be affected by osteoporosis-related issues at least once in their lifetime. Additionally, because of the increasing share of older people in the population, the total number of osteoporotic fractures will increase globally with the aging population over the next several decades (2, 6). Therefore, it is of interest to comprehend and research the possibilities to improve and build a strong skeleton while women are young to middle-aged. Especially considering the social and economic burden as well as other osteoporosis-related injuries women are at a higher risk due to the significant loss of BMD during perimenopause. It can both be interesting and helpful for future prevention and treatment of women's bone health, such as osteoporosis, to know if PA can positively affect women's BMD and if it can, to what degree (4 - 6)?

Research question: Can (individual) physical activity have a positive effect on bone mass density in women prior to perimenopause?

Methods

The literature search was conducted until 25.03.2022 by using the database “PubMed”. The keywords for the literature search were “premenopausal osteoporosis”, “prevention” and “physical activity”, they were connected by using “and” between each of the keywords. This provided an initial 159 articles. Inclusion criteria were 1) Written in English and 2) Conducted on human women. Additionally, the filter 19-44 years was applied to the search on the website. This reduced the articles to 98. Furthermore, the words “premenopausal”, “physical activity” and/or “osteoporosis” had to be included in the title of the article. Exclusion criteria were 1) Studies that focused on other/multiple diseases and/or injuries, 2) Included peri- and postmenopausal women, and 3) Studies that were subject to subscriptions or one-time payments to read. This left 8 relevant original articles of interest for this literature study.

Flow chart


Data Base:
PubMed
Keywords:
«Premenopausal osteoporosis" and "prevention" and "physical activity"
Literature:
159 relevant articles
Inclusion and exclusion criteria:
Inclusion criteria were English written studies, conducted on women, aged from 19-44 years and the title had to include one or more of the keywords "premenopausal osteoporosis", "prevention and "physical activity".
Exclusion criteria were studies focusing on other/multiple diseases/injuries, including peri- and/or postmenopausal women, and studies subject to subscriptions or a one-time payment to read
8 relevant articles:
- Brewer et al. (1983)
- Greenway et al. (2015)
- Hara et al. (2001)
- Heinonen et al. (1999)
- Mein et al. (2004)
- Saravai et al. (2013)
- Tucker et al. (2015)
- Vainionpää et al. (2005)

Results

The main findings, results and original articles used for this literature study are presented in table 1. A total of 8 articles investigated the effects of PA on BMD in premenopausal women. The subjects from all the selected studies are female. There are three randomized control trials (RCT) that included a total of 269 women who were divided into a control group and an intervention group. There were five observational studies (OS) that included 433 women. Leading to a total of 702 subjects, this number includes participants who withdrew during the study.

Table 1. Descriptive overview of original studies

Article	Study design	Participants (n)	Mean age	Purpose	Primary findings
Heinonen et al. (1999)	RCT	Total (*n*)=89 (84) Intervention (*n*)=30 *(39)* Control (*n*)=19 *(45)*	35 – 45 years	Evaluated if voluntary, unsupervised aerobic and step training could maintain the general skeletal health benefits in premenopausal women.	High impact training showed a significant increase in BMD amongst premenopausal women. It was suggested that this can be maintained with subsequent, less-demanding aerobics and step exercises.
Vainionpää et al. (2005)	RCT	Total (*n*)=120 Intervention (*n*)=39 (21) Control (*n*)=*41 (19)*	38.5 ± 1.6 years control 38.1 ± 1.7 years intervention	Evaluated the effects of high impact exercise on premenopausal women's BMD.	High impact exercise improved BMD amongst premenopausal women. This form of exercise is considered to be a safe, efficient, and cheap way to prevent osteoporosis later in life.
Tucker et al. (2015)	RCT	Total (*n*)=60 Intervention I (*n*)=23 Intervention II (*n*)=14 Control (*n*)=23	41.09 ± 4.3 years intervention I 39.79 ± 4.8 years intervention II 37.65 ± 6.4 years control	Determined the effects of two jumping programs on BMD amongst premenopausal women.	High impact jumping had improved BMD in premenopausal women, especially in their hips.

Brewer et al. (1983)	OS	Total (*n*)=80	37.7 ± 0.8 years	Investigated the skeletal status in two groups of premenopausal women. One group consisted of female marathon runners and the other of sedentary women.	The results showed that mean values for BMC and bone density were greater in the marathon runners when compared to the group of sedentary women.
Greenway et al. (2015)	OS	Total (*n)*=152	40 ± 9.6 years	Examined the relationship between aBMD and estimates of historical PA, current strength, and cardiovascular fitness in middle-aged premenopausal women.	Past PA with intensity at 7-METS or above was positively associated with greater BMD and women should continue with PA at this level to continue to acquire the positive effects on BMD.
Hara et al. (2001)	OS	Total (*n*)=91	30.6 ± 5.9 years	Investigated the effects of PA during teenage years on women's current BMD.	Historic PA in junior-, senior high, and present-day PA show a significantly higher BMD compared to the women who were not physically active during these three time periods.
Mein et al. (2004)	OS	Total (*n)*=62	18.5 ± 0.3 years	Observed the effects of dietary calcium intake and PA on longitudinal changes in BMD over almost a decade.	During the follow-up at 9 years, it appeared that young healthy women were experiencing a slight decline in BMD at the proximal

					femur. However, being physically active contributed to maintaining BMD and was considered to be a positive factor in preventing fractures later in life.
Saraví et al. (2013)	OS	Total (*n*)=48 Sedentary I (*n*)=16 Maintenance II (*n*)=16 Sports team III(*n*)= 16	I33.5 ± 5.8 years II 34.0 ± 5.0 years III 32.4 ± 8.5 years	Investigated if the intensity level of PA had a positive effect on BMD in premenopausal women.	The sports team had a higher BMC, NFSTM and lower mass when compared to the sedentary and maintenance groups, this included BMD. Further PA above the recommended levels for PA was beneficial for bone health in young to middle-aged women.

aBMD = Areal bone mineral density, BMC = Bone mineral content, BMD = Body mass density, METS = Metabolic equivalents, OS = Observational studies, NFSTM = Non-fat soft tissue mass, PA = Physical activity, RCT = Randomized controlled trial, Red numbers represent withdrawn participants

Main findings

There were three RCT studies that investigated the effects of high impact training in BMD in premenopausal women. Heinonen et al. (3) found that high impact exercise significantly increased the BMD in the lumbar spine and femoral neck in premenopausal women. Vainionpää et al. (1) found that regular high impact training significantly increased BMD in weight-bearing bone sites in the lower extremities among premenopausal women. Tucker et al. (11) discovered a significant improvement in hip BMD amongst the premenopausal women who performed the high impact jumping programs.

Five OS studies investigated the effects of general PA, weight-bearing PA and high impact PA in premenopausal women. Brewer et al. (10) discovered a significant difference in BMD amongst middle-aged premenopausal women with different PA levels, where the physically active women experienced a greater BMC compared to the inactive women. Greenway et al. (12) found a positive association between areal bone mass density and historical PA in adult premenopausal women, where the correlation between types of PA varied by decade and cite. Hara et al. (8) found a significantly higher BMD in young premenopausal women who were physically active during their adolescent age until middle age, compared to the inactive women during these two time periods. Mein et al. (7) identified that PA performances contributed to assisting the maintenance of BMD in the hip and intertrochanter cites of young premenopausal women. Saraví et al. (15) discovered a positive association between higher levels of PA, BMD and NFSTM in adult premenopausal women, where the BMD and NFSTM were higher in the sports team group compared to the sedentary and maintenance group. In addition to the main findings, calcium intake was tracked by all studies except by Brewer et al. (10). ˛

Discussion

The purpose of this literature study was to investigate if individual PA can have a positive effect on BMD in women prior to perimenopause. Results from the eight original articles show that there is a positive association between PA and BMD amongst young to middle-aged women (1, 3, 7, 8, 10-12, 15). There was in general an agreement that genetics, sex, and race were the dominant risk factors for BMD and that PA, particularly high impact exercise and weight-bearing activities, were beneficial for BMD amongst the modifiable risk factors.

PA is one of the risk factors that we as individuals can affect and implant into our lifestyle, and PA can be especially important for those women who do not wish to be treated with hormone replacements, such as estrogen (5). The reasoning for this may vary. It may be because they have other illnesses, are on other types of medication, cause unwanted side effects, or for other personal reasons (4, 16). For some individuals being physically active might just be as effective as estrogen treatments and for some even more effective (4). The World Health Organization´s guidelines for recommended PA and sedentary behavior is that adults (aged 18-64) should perform muscle-strengthening activities at a moderate or greater intensity that involves major muscle groups two or more days a week. World Health Organization also advises adults to "*perform at least 150-300 minutes of moderate-intensity aerobic PA; or at least 75-150 minutes of vigorous-intensity aerobic PA*" (17). On the other hand, the National Health Services in England recommend performing weight-bearing exercises to help maintain strong and healthy bones. Whereas Norsk Helseinformatikk recommends that women should generally just be physically active to help maintain the BMD in women during perimenopause (16, 18). This shows that there are some differences in the recommendations for PA depending on the organization and/or country.

Vainiopää et al. (1) suggested that young to middle-aged women struggle to maintain an exercise routine when compared to postmenopausal women. While Brewer et al. (10) identified that there was a decrease in PA as the female participants aged. Where the decrease in PA had been implicated as a contribution to the development of osteoporosis. It is reasonable to believe that there is a struggle to maintain an exercise routine due to age, and numerous family and career obligations, therefore maintaining an exercise routine can be challenging. However, after premenopausal age and retirement, one would think that there would be an increase in time that could be used to be more active. Unfortunately, the statistics about the decreasing PA

with age say otherwise. However, Saraví et al. (15) raised the issue of the different recommendations for PA and the lack of information about the potential benefits of higher levels of PA than recommended. According to their study, being more active than the recommendations for premenopausal women was associated with a higher bone mineral content and higher BMD. One can therefore encourage women to exceed the recommendations for PA based on these results. However, changing treatment plans or recommendations solely based on one single study is not common practice.

The window of opportunity

Childhood and young adulthood are commonly known as the "window of opportunity". During this time the body develops an optimized response to exercise, PA has an important effect on developing peak bone mass and therefore good general skeletal health. It is also the time we are most impressionable, so developing a healthier lifestyle and exercise routine can be more feasible than changing our habits at a later stage in life. The window of opportunity is therefore the prime time for building the best possible foundation for future health (12). Further, the study done by Hara et al. (8) addresses the topic of moderate levels of PA during the entire lifespan, starting from childhood, which can result in a considerable long-term improvement in the mechanical competence of the skeleton. They observed that there was a positive correlation between BMD and PA. Additionally, it turns out that PA through work can have a positive effect on BMD. The study performed by Brewer et al. (10) concluded that there was a higher incidence of osteoporosis in sedentary workers (47%) compared to workers where hard physical labor was common (23%). Based on these results it can be suggested that general activity can be enough for good bone health and BMD in young to middle-aged women. It can therefore be smart to motivate children to be physically active in their childhood to optimize their peak bone mass and for young to middle-aged women to be physically active throughout their entire life to maintain their BMD.

High impact activities/exercise on BMD in young to middle-aged women

Vainionpää et al. (1) pointed out the beneficial effects of PA by performing high impact exercises. The young to middle-aged women who performed high impact exercises increased their BMD in their lower extremities. These activities appear to have a great positive influence on general bone health. Further, The Bone Health and Osteoporosis Foundation suggests that aerobics and step appear to have a sufficient effect on BMD (19). Where they also have a list

of more concrete examples of what women can do for high impact activities when compared to the selected studies. Some examples of high impact weight-bearing exercises are dancing, aerobics, hiking, jogging, and tennis. It is important to note that women that have had osteoporotic fractures previously or are at a risk for osteoporotic fractures should be careful with high impact exercises like this (11, 19). For those women, the elliptical machine, performing low-impact aerobics, or walking at a higher pace would be more suitable according to The Bone Health and Osteoporosis Foundation. However, walking might be considered more of a weight-bearing activity rather than high impact activity. These suggested activities might not increase the BMD however, it can contribute to preserving and maintaining the existing BMD (4).

There appears to be little doubt so far that PA is beneficial to the human skeleton and that high impact activity seems to be very osteogenic. Heinonen et al. (3) showed that vigorous strength and endurance exercises can maintain BMD in both premenopausal and postmenopausal women. Even though this form of PA has been proved to have a positive effect on bone health in women, it is important to evaluate if the individual is able to pursue this type of activity. Older individuals and individuals with attrition in their hips, knees or lower limbs are at a higher risk of injuring themselves due to their age and/or other health problems (3, 11). Therefore, it can be beneficial to recommend that these types of vigorous exercises be customized and age-adjusted to the individual. Additionally, they are performed in a safe environment and maybe even with the supervision of a physician.

Weight-bearing activities/exercise on BMD in young to middle-aged women

Performing weight-bearing activities and exercises for improving muscle strength during adolescence and middle age can help in the prevention of fractures related to osteoporosis later in life (15). This is because fall-related injuries are considered one of the most common reasons for osteoporotic fractures and with better balance and strength women might be able to avoid falling altogether (16). Saraví et al. (15) mentioned that PA may be a useful resource for improving muscle strength and preventing falls in peri- and postmenopausal women and Greenway et al. (12) specifically mentioned activities that feature weight-bearing and/or activities that have strong muscular contractions. Further, The Bone Health and Osteoporosis Foundation addresses that weight-bearing activities and muscle-strengthening exercises are considered an important form of PA when it comes to building and maintaining BMD in

women (19). For improving muscle strength, they recommend lifting weights, using elastic bands, performing movements with your own body weight, and functional movements. This coincides with findings in several of the studies in this literature study.

Lifestyle factors on BMD

In the introduction, lifestyle choices were mentioned as one of the main risk factors that we as individuals can affect in regard to our BMD and that hormone replacement therapy can be unwanted for some women. Mein et al. (7) argued that one of the best treatments aside from hormone replacement therapy is lifestyle modifications. However, even though the results from this study on lifestyle changes other than PA were rather small, it is important not to ignore them. Greenway et al. (12) addressed that other than PA, nutrition appears to be one of the "major players" amongst the modifiable lifestyle factors that can contribute to good bone health.

Hara et al. (8) had an interesting observation that the two are somewhat dependent on each other and may not affect the bones independently. To acquire the positive effects of PA, you need an intake greater than 1000 mg/day of calcium. This goes to show that there are several aspects that can and do contribute to women's bone health. Considering that the results from Hara et al. (8) are co-dependent it can be challenging to differentiate the results. On the other hand, a study completed by Welton et al. (20) believed that exercise can be seen as a larger significant determinant for BMD in women than calcium intake is, and therefore not so co-dependent on each other as Hara et al. (8) initially claimed. Furthermore, an argument can be made about the importance of tracking calcium intake during research like this. Calcium is one of the main building blocks for the development of a healthy skeleton and can therefore affect BMD (6). By continuing to investigate issues like this and continuing with additional research, it can be easier to develop educated recommendations for young women about the risks associated with BMD and osteoporosis. The regularity and stability of PA in regard to the association between PA and BMD at all sites suggest that PA may have a positive effect on lifetime BMD according to the results. Other aspects that can potentially affect BMD in young to middle-aged women according to Mein et al. (7) were weight, lean mass, fat mass and alcohol consumption. However, most of these aspects are a result of dietary habits and levels of PA.

Strengths and vulnerabilities

Mein et al. (7), Saraví et al. (15) and Hara et al (8) also raised the importance of accurately identifying the risk factors that influence changes in BMD during the time prior to perimenopause. Previous studies have reported inconsistent findings; however, this might be due to inconsistent measuring methods, small sample sizes and there need to be longer follow-up studies. Therefore, it can be safe to say this area needs more attention and research.

In the past, there has been insufficient research and therefore knowledge on women and their health. One of the very positive outcomes of conducting research like this is that it can contribute to increasing the knowledge, both in the health profession and for the general women on the street (21). Further, researching the potential preventative measures for BMD in women and osteoporotic fractures can have a positive effect on the economic burden. Another strength of research on PA's effect on BMD in women is that there appears to be a large interest amongst women to participate in research tailored for women's health. This can be seen by comparing the number of participants to the total number of women interested prior to the inclusion/exclusion phase. However, several of the studies commented that because of the strict inclusion and exclusion criteria women who wanted to contribute to the studies were not eligible to be included. This is unusual considering that several studies can struggle to recruit enough participants for their sample size.

The definition of the different stages and age groups varies which can lead to an increased difficulty when one wants to compare or conduct research on this topic. Additionally, studies based on/or including the female menstrual cycle can be difficult to conduct with absolute and precise inclusion and exclusion criteria, which potentially can affect the results. This is because the menstrual cycle has no "one size fits all". It can therefore be difficult to precisely determine the different stages and transitions from premenopause to perimenopause, and perimenopause to postmenopause (4, 5).

There was a total of 702 female subjects, which also included the participants who withdrew at some point. The more intense the intervention was and/or the duration of the studies, the higher the dropout rate was. These two factors can be considered a limitation because they can affect the validity of the results in the selected original articles. As a result of the small sample size, due to really specific research and/or the strict inclusion and exclusion criteria is that it

can be more challenging to generalize. The results, and therefore the accumulated advice on what to do, are based only on a woman that was within the right criteria. It is possible that this may lead to women who were excluded from the studies, might not respond the same way to PA as the included participants. Therefore, it is possible to argue that the advice, protocol and treatments accumulated from these studies are not representative of the general female population. A potential solution for this can be to do additional and/or new research with other inclusion and exclusion criteria.

It was observed that the oldest study was conducted by Brewer et al. (10) in 1983 and the newest was conducted by Greenway et al. (12) and Tucker et al. (11) in 2015. There are 32 years between them, where the oldest study is 39 years old today. It is therefore important to consider the relevance and accuracy of the oldest studies. This might, however, be a result of the method used in this literature study as it potentially can affect both the number of relevant articles and what articles we were able to find using the inclusion and exclusion criteria alongside the keywords.

Public health implications

Since instances of osteoporosis are increasing and more women are experiencing injuries caused by skeletal fragility, it is highly critical that this research field is explored further. Future research on PA's effect on BMD in young to middle-aged women should consider including aspects such as the nature, frequency, and intensity of PA as well.

It is reasonable to believe that due to the individuality during the different phases that research can be affected by this, just like this research has been. Providing information about the potential health benefits of PA from an earlier age can potentially lead to women, in general, becoming more aware of the risks associated with fragile bones and therefore becoming more active. This can in terms lead to a potential reduction of the economic burden, and an argument can be made that this kind of research will be all that more important.

Conclusion

The purpose of this study was to investigate if PA prior to perimenopause could have a positive effect on BMD in young to middle-aged women as PA is one of the risk factors that we as individuals can control and implement at any time in our lifestyle. Some might need approval from their physician or supervision from a professional. Based on this research, it is clear that PA contributes to increasing BMD prior to peak bone mass and maintaining and preserving BMD in women after peak bone mass is reached. It has been emphasized that PA during women's younger years is crucial to obtain the best possible peak bone mass to have the best possible foundation. Lastly, it is important that women adapt to an active lifestyle that they can maintain because PA can be a very valuable tool for the primary prevention of poor bone health.

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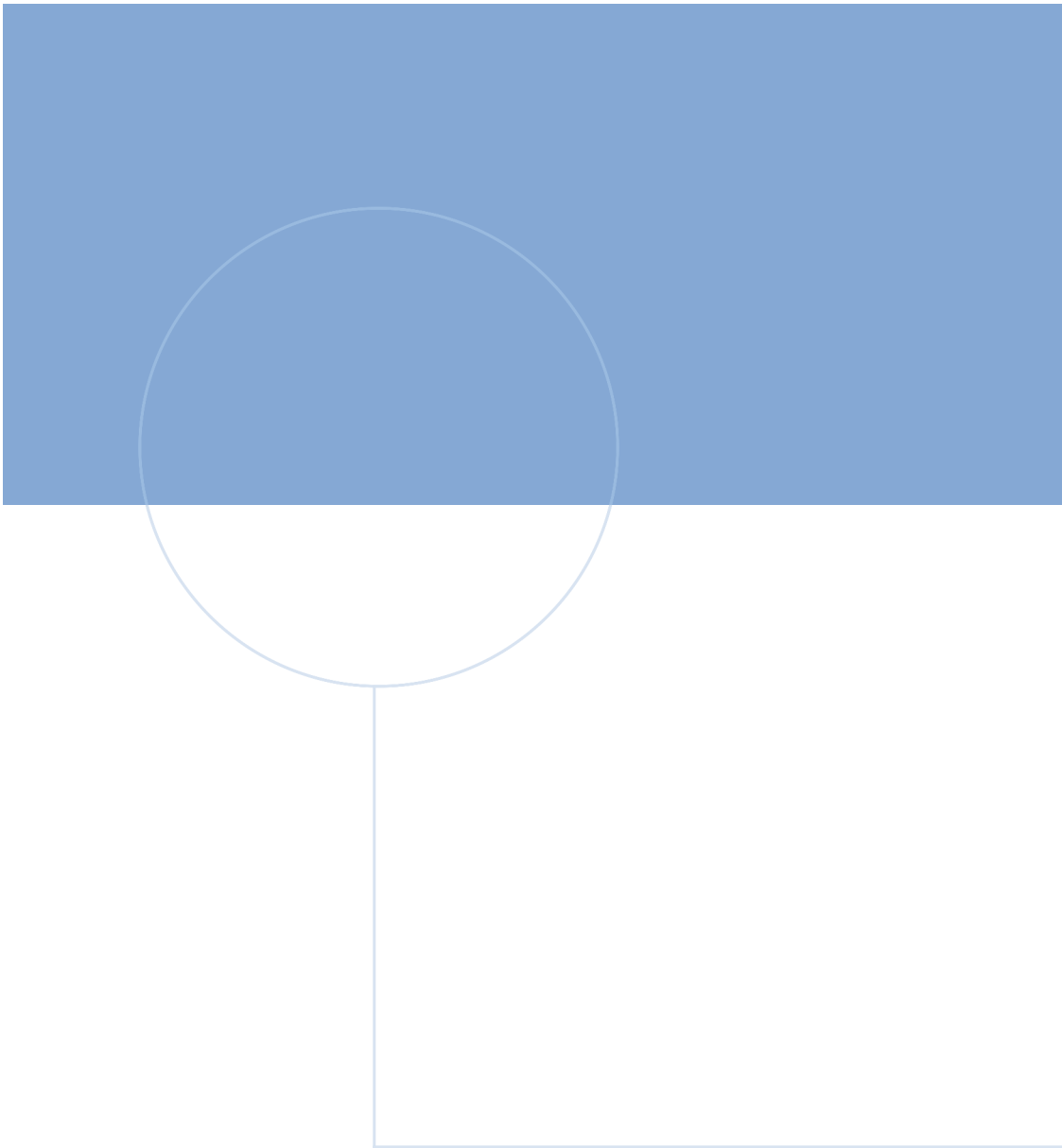

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