Bachelor's thesis

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

Anna Emilie Engebretsen
Embla Abel Fagerholt

Resistance training in premenopausal women and osteoporosis prevention

BEV2900 - Spring 2023

Bachelor's thesis in Human Movement Science
Supervisor: Xiao-Mei Mai
May 2023

NTNU
Norwegian University of Science and Technology

Anna Emilie Engebretsen
Embla Abel Fagerholt

Resistance training in premenopausal women and osteoporosis prevention

BEV2900 - Spring 2023

Bachelor's thesis in Human Movement Science
Supervisor: Xiao-Mei Mai
May 2023

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

NTNU
Norwegian University of
Science and Technology

Abstract

Osteoporosis is a common disorder that is characterized by reduced bone mass and strength and increased fracture risk. The higher mortality rates associated with osteoporosis fractures, coupled with the high cost of treatment, makes it an important disorder to prevent. Because of the natural reduction of estrogen after menopause more women are diagnosed with osteoporosis than men. Furthermore, resistance training has become more popular among premenopausal women which is why we wanted to explore the effect of resistance training in premenopausal women on prevention of osteoporosis. The method used was a literature search where eight original articles were identified. The results from the original articles showed both regional and total bone mass changes, but most of them did not show statistically significant results. There were several weaknesses identified in these studies that might explain the lack of significance. We conclude that it is unclear whether resistance training in premenopausal women has an preventative effect on osteoporosis. This is because although the changes observed were not statistically significant they might be clinically significant. Further research should include a better definition of resistance training and should study the relationship between intensity of training and changes in bone mass as well as exercise choices.

Abstrakt

Osteoporose er en vanlig sykdom som er karakterisert med redusert beinmasse og beinstyrke og økt risiko for beinbrudd. Høy dødelighet assosiert med osteoporose brudd, og høye behandlingskostnader gjør forebygging svært viktig. På grunn av den naturlige reduksjonen av østrogen etter menopause, har flere kvinner diagnostisert osteoporose enn menn. Videre har styrketrening blitt mer populært hos premenopausale kvinner, derfor ønsker vi å undersøke om styrketrening hos premenopausale kvinner har en mulig forebyggende effekt mot osteoporose. Metoden brukt i dette studiet er et litteratursøk hvor det ble identifisert 8 originale artikler. Resultatet viser regionale og totale endringer i beinmasse i alle studiene, men de fleste endringene var ikke statistisk signifikante. Det ble identifisert flere svakheter ved studiene som kan forklare mangelen på statistisk signifikans. I denne studien konkluderte vi med at styrketrening hos premenopausale kvinner har uklar forebyggende effekt siden endringene observert kan være klinisk signifikante selv om de ikke er statistisk signifikante. Videre forskning burde ha tydeligere definisjoner av styrketrening, samt undersøke relasjonen mellom intensitet og beinmasse, og øvelsesutvalget.

Resistance training in premenopausal women and osteoporosis prevention

Introduction

Osteoporosis is a common disorder that affects a lot of people, especially postmenopausal women. Osteoporosis is characterized by reduced bone mass and strength which increases the risk of fractures (1). A person's bone strength is determined by bone mineral density (BMD) and bone quality, where BMD is determined by peak bone mass and amount of bone loss. Bone quality however, refers to the bone architecture, turn over, damage accumulation and mineralization of the bone (1). Furthermore, osteoporosis can be divided into different sub groups based on the underlying cause of the disorder: primary and secondary osteoporosis
Primary osteoporosis can be caused by natural aging, menopause in women, physical inactivity, smoking, alcohol consumption or nutrient deficiency.
Secondary osteoporosis is caused by diseases, like celiac disease, or medication such as glucocorticoids (1,2).

Osteoporosis can have many consequences that affect not only the patient, but also the family, their community and society as a whole.

For the patient with osteoporosis there is an increased risk for all types of fractures, and the hip and vertebral fractures are associated with increased morbidity and mortality. A study from Sweden showed that after a hip fracture the mortality rate was higher than for the general population (3). For example the 5 year mortality rate for men aged 50 with a hip fracture was 17.3-21.3 while it was 2.44 for the general population. The study also suggests that 24% of all deaths associated with hip fractures are causally related to the fracture itself. The percentage and mortality rate will vary depending on age. For people aged 60, deaths associated with hip fractures accounted for 1.4% in men and 2.4% in women. While at the age of 90 the percentage was 10.6 and 11.4 for men and women respectively (3).

This shows how detrimental osteoporosis can be for the individual and their families but it also highlights how much resources are needed to treat osteoporosis related fractures. In Norway the average cost of a hip fracture is 640 000 NOK within the first year and there are 9000 hip fracture operations yearly (4). This gives an average cost of 5.76 billion NOK per year just for hip fractures alone. It is estimated that 140 000 women and 90 000 men over 50 years of age in Norway have different types of vertebral deformities and fractures that may have been caused by osteoporosis. An unknown number of these people suffer from chronic pain associated with vertebral fractures (5). A study done in Tromsø found the prevalence of vertebral fractures to be 11.8% for women and 13.8% in men (6). Based on this it is safe to assume that the cost of all fractures caused by osteoporosis in Norway is a lot higher than 5.7 billion NOK per year.

There are two interesting things to note about osteoporosis in Norway. One, Norway has some of the highest incidence of osteoporosis hip fractures in the world. The reason for this high incidence is still not known. However, in the last decade the increase in incidence of hip fractures in women in Norway has slowed down. The same has not yet happened for men living in Norway (7). This decrease in incidence is not seen in the other forms of osteoporosis fractures in Norway. Second, there is a regional difference in hip fracture incidence where an east-west gradient is observed, with the highest incidence in the southeast. There is also a north-south gradient where the incidence is highest in the south. The regional differences are still apparent even with the decrease in hip fracture incidence (8).

"Menopause" in women refers to a woman's last menstrual period which indicates the end of fertility. This last period often occurs around the age of 45-55 but it can vary from 40-60. The cause of menopause is the reduction in estrogen production in the ovaries and this causes many changes to the female body. That is why a postmenopausal woman's body will have some different physiological function than peri- and premenopausal women. Perimenopausal is the same term as "overgangsalder" in Norwegian. This refers to years before menopause, where estrogen production is starting to fall and around the time women might start to notice different menopausal symptoms. In this stage of life, the physiological functions in women are starting to change but it will not be as noticeable as after menopause. Premenopausal means before menopause and is commonly used for women between the age of 20-40. This term is meant to describe women where the reduction of estrogen production has not yet occurred.

Menopause is a state of change that all women go through, and this change in estrogen production does have big consequences for the body. One of these consequences is the rapid loss of BMD. Studies with comparisons of pre- and postmenopausal athletes suggest that even very vigorous levels of physical activity do not prevent the menopause induced loss of BMD (9). Since the BMD loss can't be fully prevented after menopause, and peak BMD is reached in the first 3 decades of a person's life the BMD attained early in life might be the most important determinant of lifelong skeletal health (1). This is why we want to study premenopausal women. Furthermore, BMD values tend to be higher in athletes that do sports involving high intensity loading forces like gymnastics and weightlifting, and lowest in non-weight bearing sports like swimming (9**.** This suggests that training methods used in these types of sports are better to increase BMD than other training methods. In recent years resistance training has become more popular through the Norwegian population. In 2001 only 18% of the Norwegian population reported doing resistance training while in 2019 it was 46% (10)**.** This type of exercise is especially popular in younger adults aged 18-29 where it has been observed that 65% of men and 55% of women perform strength training regularly (11)**.** Therefore, we wanted to explore if the literature shows that resistance training at a younger age has an effect on BMD in postmenopausal women.

Method

A literature search was done using the databases PubMed and SPORTdiscus. The keywords "Bone mass", "Bone mineral density", "premenopausal", "young adult women", "resistance training", "weight training" and "strength training" were used. The keywords ``young adult women " and "premenopausal" were used in separate searches since the use of both together combined with the other keywords gave too many unrelated sources. The first search where "premenopausal women" was used with the rest of the keywords , gave 45 articles at PubMed while young adult women gave 336 sources. The same keywords on SPORTdiscus gave 12 sources. When we went through these publications, we looked for articles with the specific keywords mentioned above in the title. We also looked for articles with different types of resistance training. After this first work through we were left with 35 articles. From these 35 articles we looked more thoroughly with these exclusion criteria in mind:

1. Training in postmenopausal women.
2. Articles containing other illnesses as well as osteoporosis
3. Pharmaceutical intervention to prevent osteoporosis.
4. Studies done on men
5. High impact training

After 15 sources were excluded, 10 were left. Of these 10 studies three were excluded as only the abstract and not the full publication. Seven studies remained, and additionally one review from the reference list of one of these publications was found. See Figure 1 for a flow chart describing the literature search.

Inclusion criteria	Exclusion criteria
Strength training/recistance training/Weight training	Postmenopausal women
Premenopausal women	Other illnesses as
Young women	Pharmaceutical intervention
Bone mass	Men
Bone mass density	High impact training
Osteoprosis	

Table 1: Inclusion and exclusion criteria

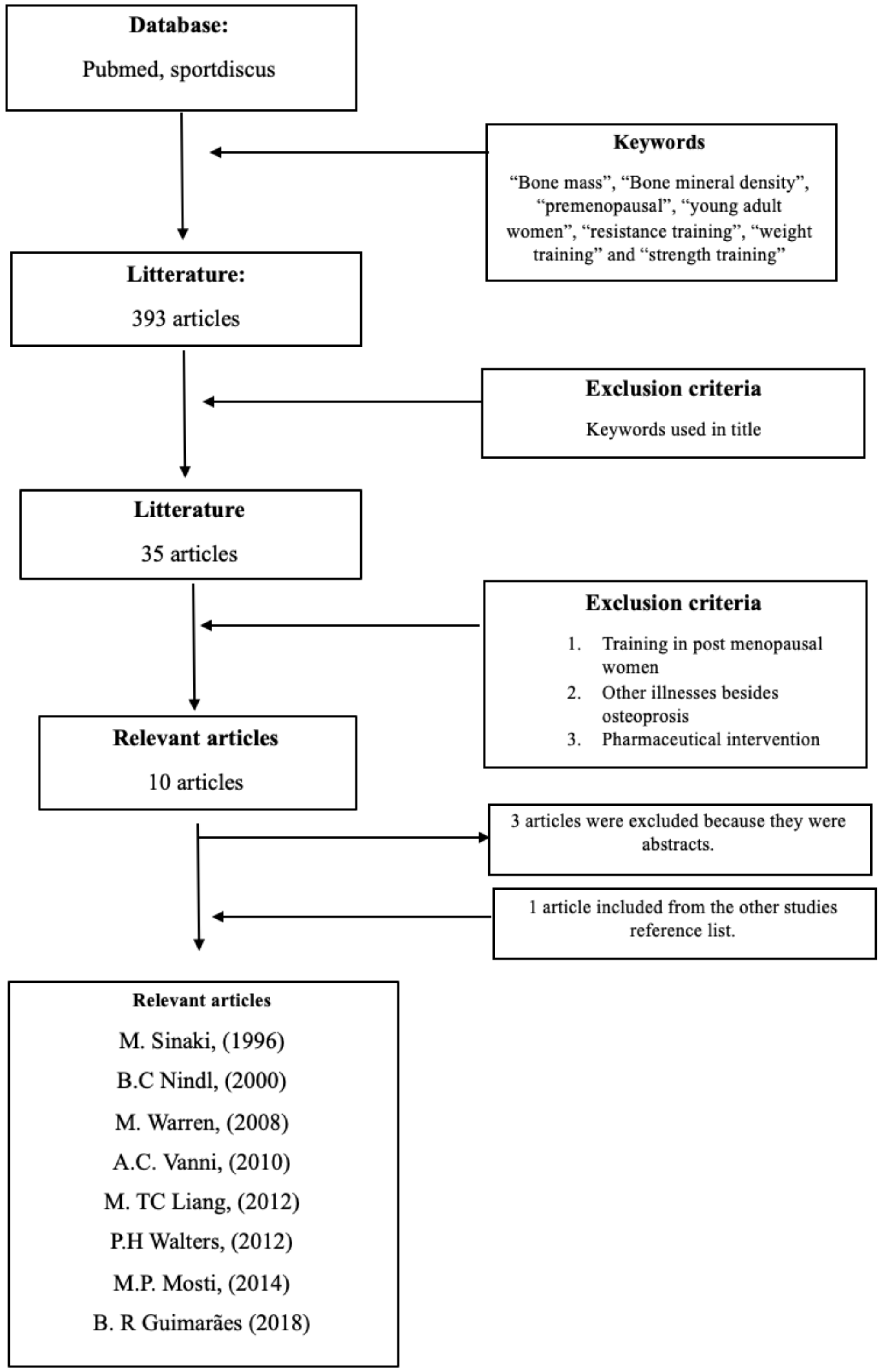

Figure 1: Flow chart for the literature search

Results

Warren et al. conducted a randomized control trial (RCT) with 2 years observation time to explore whether strength training following public guidelines has an effect on BMD and bone mineral content (BMC) in premenopausal women (12). The cohort included 164 premenopausal women aged 25-44. At the end of the study data from 46 participants were lost and substituted with data from control experience. Measurements were performed at baseline, 1 year and 2 years. BMD and BMC at proximal femur and lumbar spine were measured by dual x-ray absorptiometry (DXA) while muscle strength was assessed with a one repetition maximum (1 RM) test in both the bench press and leg press. The training protocol consisted of twice-weekly strength training of three working sets of 8-10 repetitions using machines and free weights.The measurement from the femoral neck showed no change in BMC for the strength training group (STG) over the 2 years while the control group (CG) showed a 1.5% decrease in the same time period. The between-group effects were statistically different (P = 0.04). At the other sites of BMC and BMD measurement, no statistically significant difference between the groups was found.This strength training intervention did not show any effect on total BMC or BMD when pooled across all sites (12).

Sinaki et al conducted an RCT over 3 years to study the effect of spinal muscle strengthening on lumbar spine BMD as well as the effect of upper extremity loading on middle radius and femoral BMD in healthy premenopausal women (13). The cohort included 120 premenopausal women aged 30-40. Of the 120 women, 60 were in the strength training group (STG) and 60 in the control group (CG). 24 women withdrew from the study at baseline and at the end of the 3 years a total of 53 women were no longer participating in the study. BMD of the lumbar spine, greater trochanter, femoral neck and Ward's triangle were measured using a DXA scan at baseline, 1 year and 3 years into the study. The maximal strength measurements of the back extensors and flexors, hip extensors were done with an isometric strain-gauge dynamometer. The training protocol consisted of back extension with 30% of max strength and shoulder exercises at 10 RM. This was done three times a week for three working sets with 10 repetitions. Intensity was increased every three months by taking new strength measurements (13). From baseline to year 1, mean lumbar spine BMD increased slightly with 0.006 g/cm^2 in the STG and decreased with -0.002 g/cm^2 in the CG. When the study population was stratified at baseline BMD, they found among the subjects with lower BMD mean lumbar spine BMD increased with 0.009 g/cm^2 (SD 0.019) in the STG, while there was a slight decrease of -0.006 g/cm^2 in the CG (SD 0.023) which was a significant difference ($p = 0.039$). This effect was not significant for the 3 year change in lumbar spine BMD. From baseline to 3 years both groups showed a slight increase in lumbar spine BMD but the difference after 3 years was not significant ($p = 0.50$). Even after adjustment for strong compliars in the STG, the participants attending 50% or more of the exercise classes, they could not find significant changes in the man lumbar spine BMD after 3 years (0.007 g/cm^2, 0.0023 SD, $p = 0.41$). The changes observed in trochanter, femoral neck, ward's triangle and mid radius from 1 to 3 years ere also not significant between the STG and CG ($p= 0.061$) Those measurements were not significantly affected by baseline BMD values like lumbar spine BMD(13).

Nindl et al. conducted a short RCT over a 6-month duration to explore regional morphological changes in women after prolonged exercise (14). The cohort included 31 women aged 28 ± 4 years that were in the STG and five women that were in the CG. BMD was measured using DXA at baseline, 3 months and 6 months. The training protocol consisted of full body exercises twice a week starting at 10-12 RM but as the study progressed, the intensity increased. The participants did not perform consecutive sets of an exercise, instead they did groups of two to three exercises doing one set each until they were done. In this study no significant difference in BMD was found and the data was not shown in the results.

Vanni et al. conducted an RCT of 28 weeks duration to compare the effects of linear and nonlinear periodized strength training on BMD, muscle strength, anthropometric and muscle damage variables in premenopausal women (15). The cohort consisted of 30 premenopausal women aged 39,6 ± 0,41 years and at the end of the study three participants dropped outMeasurements were taken at baseline and at 6 months and the lumbar spine and right femoral neck BMD was measured using a DXA. The 1 RM and 20 RM test was used to determine the intensity the training protocol would follow. The training protocol consisted of different full body exercises using machines and free weights done three times a week. The intensity started at 18-20 RM and the participants did consecutive sets of an exercise before moving on to the next. One of the exercise groups followed a linear progression (LPG) over time, while the other followed a non-linear one (UPG). In this study mean lumbar spine BMD at baseline was 1.207 g/cm^2 ±0.031 and the mean femoral neck BMD was 1.011g/cm^2 ± 0.023 in the LPG. After the training intervention the mean lumbar spine BMD was 1.208

g/cm^2 ± 0.031 and the femoral neck BMD was 0.999 g/cm^2 ± 0,025. For the UPG the mean lumbar spine BMD at baseline was 1.231g/cm^2 ± 0.025 and the mean femoral neck BMD was 1.039 g/cm^2 ± 0.024. After the training intervention the mean lumbar BMD was 1.230 g/cm^2 ± 0.025 and femoral neck BMD was 1.025 g/cm^2 ± 0.026. The difference between the lumbar spine and femoral neck BMD between the LPG and UPG was not statistically significant with p= 0.329 and p=0.29 respectively.

Mosti et al conducted an RCT over 3 months to investigate the musculoskeletal effects of high acceleration maximal strength training in premenopausal women (16). The cohort consisted of 30 healthy women aged 22 ± 2 years. Only one participant withdrew from the study, leaving a total of 29 participants. BMD of the lumbar spine, and hip were measured using DXA at baseline and at 3 months. The 1 RM strength test was done in the same squat exercise machine and was done from straight legs to 90 degrees angle between the front side of the lower leg and upper side of the thigh and up again. The training protocol consisted of one squat machine exercise done three times a week. The intensity was at 85-95 % of 1 RM four to five repetitions for four working sets. From this training intervention lumbar spine BMD increased by 2.2% (p=0.01) and the lumbar spine BMC increased by 3.4% (p=0.01) in the STG. In the CG no changes were found. Lumbar spine BMD and BMC increased more in the STG than in the CG (p=0.001 and p=0.011 respectively). Intertrochanteric BMD improved by 1.0% (p=0.016) and the total hip BMD improved 1.0% (p=0.01) in the STG whereas no changes appeared in the CG. Total hip BMD also improved more in the STG than in the CG (p=0.022), but no changes in whole-body BMD was found in either group (16).

Liang et al conducted an RCT over 10 weeks to examine the effect of short-term upper-body resistance training on muscular strength, bone metabolic markers and BMD in premenopausal women (17). This cohort consisted of 22 women aged 22.1 ± 1.8 years. BMD of the left wrist, distal half of ulna and radius, and the heel were measured using DXA at baseline and at the end of the training intervention. The training protocol consisted of two supervised resistance training sessions a week plus one self-directed elastic band training day a week. The intensity was at 50-60% of 1 RM with 10-12 repetition for two to three series for both the resistance training and band training. From this short-term intervention there was significant improvement in strength performance but not in BMD of the wrist, distal half of ulna or radius, all p>0.05.

Guimarães et al studied the influence of muscle strength on BMC and BMD among premenopausal women (18). The cohort consisted of 15 women aged 24.9 ± 7.2 years and BMD, BMC and whole-body composition were measured at baseline using a DXA. The training protocol consisted of 1 RM test in the following exercises: horizontal bench press (BP), Lat pull-down (LPD), knee extension (KE), leg curl (LC) and leg press 45 degrees (LP45). From this study only whole-body lean mass (37.52 kg ± 2.71 kg) was associated with almost all BMC and BMD values. The exception was for whole-body and upper limb BMD. The other lean mass values, upper limb (UL), lower limb (LL), and trunk (T), correlated with BMC except for lumbar vertebrae. Only the BMD of the LL was related to the lean mass of that area. This study also noted that whole-body lean mass presented a greater potential than regional values in determining BMC and BMD both regional and whole-body. Furthermore, the strength values from the 1 RM test, except knee flexion exercises, correlated with regional BMC and BMD values for LL. The same was the case for whole-body BMC values. The study also notes that knee extension exercises correlated with whole-body and regional BMD and BMC except for the lumbar spine. Finally, this study also showed that BP exercises also correlated with regional whole-body BMD and BMC values except for the pelvic region.

Walters et al. did a case study to examine the BMD of two elite female powerlifters aged 48 and 54 who had engaged in more than 30 years of high intensity resistance training (19). The BMD and BMC were measured at lumbar spine, dual femur and total body using a DXA. In the youngest women lumbar spine BMD were 1.40 g/cm^2 and a BMC of 74.47 g. The femoral mean BMD was 1.08 g/cm^2, BMC was 31.81 g and whole body BMD 1.29 g/cm^2 and BMC was 2703.00 g. For the oldest women total lumbar BMD and BMC was 1.44 g/cm^2 and 66.22 g, while femoral neck mean BMD and BMC was 1.19 g/cm^2 and 37.61g. The total body BMD and BMC for that subject was 1.34 g/cm^2 and 3167.00 g. When compared to age group norms the youngest women had a Z-score of 2.2 for lumbar spine, 1.1 for femoral mean and 2.4 for whole body. For the oldest the Z-score of 2.8 for lumbar spine, 1.9 for femoral mean, and 3.0 for whole body. This indicates that BMD values for both women were higher compared to normal for their age group.

Study	Study design	Population (n)	Age (years)	Duration (years)	Results
Warren et al.	RCT	ST = 82	25-44	2	BMD showed little change and didn't differ between groups at any site.
		CG = 82			Femoral neck BMC showed a significant difference between groups.
Sinaki et al	RCT	STG = 60	30-40	3	No significant difference in BMD between groups
		CG = 60			
Nindl et al.	RCT	STG = 31	28± 4	0,5	No significant differnece in BMD and BMC between groups
		CG = 5			
Vanni et al.	RCT	LPG = 14	39.6 ± 0,41	0,5	No significant difference in BMD between groups
		UPG = 13			
Mosti et al.	RCT	STG = 15	22 ± 2	0,25	Significant differnece in BMD between groups
		CG = 15			
Liang et al	RCT	STG = 12	22.1 ± 1.8	0,2	No bone metabolic markers and BMD of the wrist can be improved with a 10 week
		CG = 10			upper-body recistance training program
Guimarães et al	Cohort	STG = 15	24.9 ± 7.2	0	BMD and BMC is assosiated with strength and whole-body lean mass
Walters et al	Case study	STG = 2	40-50		Z and T scores for both women were higher then either age and gender matched norms

Table 2: Summarized results.

Discussion

From the data collected it is hard to conclude if resistance training in premenopausal women has any effect on bone health or could be used as a possible measure to prevent osteoporosis. On the one hand, some cohort analysis like the one Guimarães et al. did indicates an association between strength levels and total body BMD and BMC as well as site specific BMD and BMC, and the case study by Walters et al. also suggest a similar association (18,19). On the other hand, other studies do not find this association.

This might be due to the differences in the design of the training protocol. The training protocols different and should include at least four general principles. 1. Training frequency; how many times a week is the training done. 2. The intensity; how high a percentage of 1 RM is lifted both for each training day and total for the period. 3. The total volume lifted throughout the training period, this is *weight lifted x repetitions x working sets*. 4. What type of exercises and exercise variations.

For the majority of the described studies the intensity was perhaps not high enough. Intensities from 50-60% of 1 RM was used in over half of the described studies and some even used a 20 RM as a starting point for the exercise protocol. This seems to be too low intensity to expect changes in the skeleton, from a perspective of systematic strength training and sports. An important factor in training to gain results is “The super compensation principle”. Changes in the muscles and skeleton are induced by heavy stimulation for periods of time, followed by reduction in the training load to assess the new baseline fitness. If this is done correctly and given enough time this would more likely induce increase in both muscle strength and bone mass. Starting at 18-20 RM intensity, as described by Vanni et al. (15), would not induce heavy enough loading, not even for a novice lifter, to produce any changes. How often the intensity increases is also important. Starting at a 10 RM, as Sinaki et al. 's 3-year RCT (13), and only increasing the intensity every 3 months, will not take into consideration the quick strength gains that every novice lifter has.These quick strength gains come from familiarity with the exercises, the technical improvements, and the quick strength adaptations in the body the first 6-12 months after training is started.

Another aspect with some of the training protocols is the training frequency. Most of protocols used a 3-times-a-week frequency but some, Warren et al. and Nindl et al (12,14), only used two times a week. This might not be a problem, but coupled with low intensity this is most likely not enough stimuli to induce change to the body. The training protocols should take into consideration that the body is reluctant to change, the concept that the body seeks homeostasis where everything is balanced, so to be able to change this balance the stimuli added must be large.

The intensity and the training frequency both contribute to the total volume of the training. So does the amount of working sets and for most of the studies that showed no significant changes in BMD and BMC for their strength training protocol they used two to three working sets. In theory there is nothing negative about this, but again since the frequency and intensity is low, the total training volume, and again the total training stimuli will be too small.

Interestingly, Mosti et al. did a study with a much higher intensity and total volume lifted (16).They used an intensity of 85-95% of 1 RM for four to five repetitions with four working sets. Compared to the other studies this is much closer to a normal strength training programme used by strength sport athletes who have a much higher BMD than normal (9,19). The results also suggest that high intensity strength training, or maximal strength training as they called it, has the same effect on BMD as concurrent strength and high impact training (20–22). This means that with high enough intensity in a strength training protocol the effect on BMD is the same as what is recognised as the best way to increase bone mass. It is also interesting to note that Mosti et al used the same training protocol on postmenopausal women with osteoporosis and osteopenia. They registered improvement of bone health markers which indicates that intensity and exercise choice happier influence the improvement of bone health (23).

Another thing that Mosti et al. did differently than the other studies is the exercise selection. In the other studies that found no significant difference in BMD, the training protocols included many different exercises using machines, free weights, and bands. Mosti et al. on the other hand used only one exercise and it was a hack squat machine. This is a multi-jointed exercise that is designed to mimic a barbell squat with extra emphasis on quadriceps activation. In other words, it loads the whole body and the participants had to use larger muscle groups and systems in order to do the exercise. This in turn makes the exercise harder which increases the total stimuli given to the body. It may be that the exercises used in the studies that gave non-significant results might themselves be the cause of the lack of significant results. From all the studies combined it is apparent that there needs to be a distinction between simply lifting weights and doing proper strength training, because both increasing strength and gaining bone mass take a lot of time and effort.

We noted in the reviewed studies the duration of the training period. Several of these studies were conducted over a short period, Most et al. 's lasted only 3 months, which means that it might not have been enough time to accurately measure changes in BMD and BMC. Many of the studies were conducted over the same amount of time for one bone turnover cycle; some were even shorter. Longer studies use more resources, and compliance from the subjects usually becomes more difficult as the studies go on. This means that the cohorts for longer studies need to be larger to make sure that the loss of compliance or general fallout from the study does not affect the quality of the statistical analysis. This would also be studies with higher costs including more people to conduct the study over a longer period of time.

Finally we want to discuss the term "statistically significant". Although changes observed in many of the reviewed studies are not statistically significant, the might still have clinical significance. Since the goal of this literature search was to examine whether strength training in premenopausal women could influence the possible prevention of osteoporosis, the distinction between statistical and clinical significance is important. The goal of established osteoporosis prevention is to both gain a larger peak BMD within the first 30 years of a person's life but also to maintain the BMD, and prevent age related bone loss later in life. Most of the studies observed some increase in BMD on different regional sites in the STG. The studies that didn't observe any BMD changes in the STG observed a decrease in the CG. This might indicate that strength training in premenopausal women has an effect on preventing bone loss and therefore an impact on preventing the development of osteoporosis in postmenopausal women. Which in turn means that the small changes observed may very well be clinically significant.

Conclusion

The present study indicates that the effect of strength training in premenopausal women on development of osteoporosis is unclear. There is a need both for further and larger studies in this area, and for more specific definitions of strength training, and to investigate the relationship between intensity training, exercise selection and bone mass.

References

1. NIH Consensus Development Panel on Osteoporosis Prevention D and Therapy. Osteoporosis Prevention, Diagnosis, and Therapy. JAMA. 14. februar 2001;285(6):785–95.
2. Ribom EvaL, Piehl-Aulin K. . Osteoporose. I: Aktivitetshåndboken: Fysisk aktivitet i forebygging og behandling. 1. utg. Oslo: Helsedirektorate; 2009. s. 454–65.
3. Kanis JA, Oden A, Johnell O, De Laet C, Jonsson B, Oglesby AK. The components of excess mortality after hip fracture. Bone. 1. mai 2003;32(5):468–73.
4. Osteoporosepoliklinikken ved Oropedisk avdeling Helse Stavanger er åpnet! [Internett]. [sitert 19. mars 2023]. Tilgjengelig på: https://www.legeforeningen.no/foreningsledd/lokal/rogaland/syd-vesten-artikler/2020/osteoporosepoliklinikken-ved-oropedisk-avdeling-helse-stavanger-er-apnet/
5. Meyer POS av: HE. Fakta om beinskjørhet og brudd (osteoporose og osteoporotiske brudd) [Internett]. Folkehelseinstituttet. 2004 [sitert 19. mars 2023]. Tilgjengelig på: https://www.fhi.no/fp/folkesykdommer/beinskjorhet/beinskjorhet-og-brudd---fakta-om-os/
6. Waterloo S, Ahmed LA, Center JR, Eisman JA, Morseth B, Nguyen ND, mfl. Prevalence of vertebral fractures in women and men in the population-based Tromsø Study. BMC Musculoskelet Disord. 17. januar 2012;13(1):3.
7. Lofthus CM, Osnes EK, Falch JA, Kaastad TS, Kristiansen IS, Nordsletten L, mfl. Epidemiology of hip fractures in Oslo, Norway. Bone. 1. november 2001;29(5):413–8.
8. Forsén L, Søgaard AJ, Holvik K, Meyer HE, Omsland TK, Stigum H, mfl. Geographic variations in hip fracture incidence in a high-risk country stretching into the Arctic: a NOREPOS study. Osteoporos Int. 1. juli 2020;31(7):1323–31.
9. Kohrt WM, Bloomfield SA, Little KD, Nelson ME, Yingling VR. Physical Activity and Bone Health. Med Sci Sports Exerc. november 2004;36(11):1985.
10. Styrketrening stadig mer populært [Internett]. ssb.no. 2019 [sitert 6. april 2023]. Tilgjengelig på: https://www.ssb.no/kultur-og-fritid/artikler-og-publikasjoner/styrketrening-stadig-mer-populaert
11. Slik er nordmenns helse og treningsvaner [Internett]. Sportsbransjen. [sitert 6. april 2023]. Tilgjengelig på: https://sportsbransjen.no/nyhetsarkiv/slik-er-nordmenns-helse-og-treningsvaner
12. Warren M, Petit MA, Hannan PJ, Schmitz KH. Strength Training Effects on Bone Mineral Content and Density in Premenopausal Women. Med Sci Sports Exerc. juli 2008;40(7):1282–8.
13. Sinaki M, Wahner HW, Bergstralh EJ, Hodgson SF, Offord KP, Squires RW, mfl. Three-year controlled, randomized trial of the effect of dose-specified loading and strengthening exercises on bone mineral density of spine and femur in nonathletic, physically active women. Bone. 1. September 1996;19(3):233–44.

14. Nindl BC, Harman EA, Marx JO, Gotshalk LA, Frykman PN, Lammi E, mfl. Regional body composition changes in women after 6 months of periodized physical training. J Appl Physiol. juni 2000;88(6):2251–9.
15. Vanni AC, Meyer F, da Veiga ADR, Zanardo VPS. Comparison of the effects of two resistance training regimens on muscular and bone responses in premenopausal women. Osteoporos Int. 1. September 2010;21(9):1537–44.
16. Mosti MP, Carlsen T, Aas E, Hoff J, Stunes AK, Syversen U. Maximal Strength Training Improves Bone Mineral Density and Neuromuscular Performance in Young Adult Women. J Strength Cond Res. oktober 2014;28(10):2935.
17. Liang MT, Quezada L, Lau WJ, Sokmen B, Spalding TW. Effect of short-term upper-body resistance training on muscular strength, bone metabolic markers, and BMD in premenopausal women. Open Access J Sports Med. 15. November 2012;3:201–8.
18. Guimarães BR, Pimenta LD, Massini DA, Santos D dos, Siqueira LO da C, Simionato AR, mfl. MUSCULAR STRENGTH AND REGIONAL LEAN MASS INFLUENCE BONE MINERAL HEALTH AMONG YOUNG FEMALES. Rev Bras Med Esporte. juni 2018;24:186–91.
19. Walters PH, Jezequel JJ, Grove MB. Case study: Bone mineral density of two elite senior female powerlifters. J Strength Cond Res. mars 2012;26(3):867–72.
20. Kemmler W, Shojaa M, Kohl M, von Stengel S. Effects of Different Types of Exercise on Bone Mineral Density in Postmenopausal Women: A Systematic Review and Meta-analysis. Calcif Tissue Int. November 2020;107(5):409–39.
21. Winters KM, Snow CM. Detraining Reverses Positive Effects of Exercise on the Musculoskeletal System in Premenopausal Women. J Bone Miner Res. 2000;15(12):2495–503.
22. Winters-Stone KM, Snow CM. Site-specific response of bone to exercise in premenopausal women. Bone. 1. desember 2006;39(6):1203–9.
23. Mosti MP, Kaehler N, Stunes AK, Hoff J, Syversen U. Maximal Strength Training in Postmenopausal Women With Osteoporosis or Osteopenia. J Strength Cond Res. oktober 2013;27(10):2879.

NTNU

Norwegian University of
Science and Technology