Bachelor's thesis

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

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Effect of strength training on bone health in healthy postmenopausal women

Number of words abstract: 199/180
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Bachelor's thesis in Human Movement Science - BEV2900
Supervisor: Xiao-Mei Mai
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Abstract

Purpose: In Scandinavia the number of osteoporosis related fractures after menopause for women, have doubled in the last 50 years. This increase in fractures is higher than seen in any other place in the world. Since it is widely acknowledged that the body adapts to strain, it can be assumed that mechanical load may improve bone mineral density (BMD). Therefore, this study will investigate if strength training may have an effect on BMD in healthy postmenopausal women.

Method: The included articles were found through a literary search using the search engines PubMed, Oria and Google Scholar using search words such as *strength training, bone mineral density* and *post menopausal women.* 8 articles were selected based on inclusion and exclusion criteria.

Result: The general consensus between the included articles seems to be that strength training over a longer period of time is beneficial for bone health in postmenopausal women. Some of the included studies found an increase, while some found no change/maintained BMD.

Conclusion: Exercise is beneficial to maintain BMD, and any exercise is better than none. Peak load seems to be more important than number of load cycles. The benefits of exercise seem to decrease when training is ceased.

Abstrakt

Formål: Antallet beinbrudd relatert til osteoporose etter menopause blant kvinner i Skandinavia har doblet de siste 50 årene. Denne økningen i frakturer er høyere enn observert noe annet sted i verden. Siden det er allment anerkjent at menneskekroppen tilpasser seg belastning kan man anta at mekanisk belastning kan ha en positiv innvirkning på beinmineraltetthet (BMD). Derfor er formålet for denne studien å undersøke om styrketrening kan ha en effekt på beinmineraltetthet blant friske kvinner etter menopause.

Metode: Artiklene benyttet i denne studien ble funnet ved hjelp av søkemotorene PubMed, Oria og Google Scholar ved bruk av søkeord som *strength training, bone mineral density* og *post menopausal women.*

Resultat: Den generelle konsensus virker å være at styrketrening over lengre tid er fordelaktig for beinhelse blant kvinner etter menopause. Noen av artiklene fant en økning i BMD, mens andre fant ingen endring/opprettholdt BMD.
Konklusjon: Trening er fordelaktig for å opprettholde BMD, og all trening er bedre enn ingen trening. Høyeste oppnådde belastning virker å være viktigere enn antall repetisjoner. Helsegevinsten man får av treningen ser ut til å avta når treningen avsluttes.

Keywords: Postmenopausal women, strength training, bone mineral density, load

Introduction

Women's bone health develops and changes throughout their life, with the most prominent changes happening during and after the menopause. Postmenopausal women experience a loss of 6-8% of bone mass per decade, which compared to men who lose only 2-3% of theirs in the same time period, makes up a significant amount of tissue. This is due to the hormonal changes that happen in the female body when the menstrual cycle ceases, and with it the production of estradiol. Estradiol is considered the most important and potent hormone in the total estrogen production, and the reduction in production correlates with the reduction of bone mineral density in postmenopausal women (Sand et al., 2014, p. 823).

The strength of a bone is determined by the quantity and the organisation of minerals. A narrow bone with the same quantity of minerals as a thicker bone, would fracture more easily because the bone tissue is organised closer to the length axis (Dahl & Rinvik, 2010, p. 214). Bone mineral density, from now on referred to as BMD, is defined by the national cancer institute as “the amount of minerals (mostly calcium and phosphorus) contained in a certain volume of bone.” (*Definition of Bone Mineral Density*, 2011) Trabecular bone tissue is made up of a porous structure and the bone tissue is organised as trabeculae parallel with the load direction. These trabeculae are interconnected by processes who play a significant part in the overall strength of the structure. When a trabeculae is connected to another by an interconnected process, the trabeculae can carry four times the weight of a single trabeculae without interconnections. Because of this, the loss of these connections has a big impact on the strength of the bone and bone tissue (Dahl & Rinvik, 2010, p. 214).

The main changes to happen during the menopause is that the ovaries run out of egg cells (oocytes), which prompts a series of hormonal changes, mainly the inability to continue producing estradiol and progesterone caused by the lack of follicles left. This further prompts the pituitary gland to increase production of luteinizing hormone (LH) and follicle stimulating hormone (FSH) in an attempt to stimulate the ovaries to continue the production of estradiol and progesterone (Sand et al., 2014, p. 822).

The majority of bone tissue, approximately 60%, is produced before and during puberty for both males and females. After this growth spurt, its density is controlled by the balance between osteoblasts and osteoclasts breaking down bone tissue, and osteoblasts' ability to rebuild bone tissue (Dahl & Rinvik, 2010, p. 216). This process is called a remodelling cycle. In every one of these cycles the amount of bone tissue broken down is slightly greater than the amount of rebuilt bone tissue. This leads to a natural age-related bone loss, as BMD seems to reach its peak during late adolescence in both men and women, with the decrease starting at around age 30 (Cohn et al., 1976; Henry et al., 2004). In addition to the age-related bone loss that happen in both sexes, females experience an additional factor of bone loss during and after the menopause. This is because the female sex hormone oestrogen has an inhibiting function on the breakdown of bone tissue (Dahl & Rinvik, 2010, p. 213; Sand et al., 2014, p. 304). After the menopause, when the production of oestrogen goes down, females experience an approximately three times higher rate of bone loss than pre menopause (Cohn et al., 1976; Warming et al., 2002). Since the remodelling of bone is connected to the surface area of bone, an increased surface area will lead to an increase in initiated remodelling cycles in both age and postmenopausal related bone loss. As remodelling cycles often lead to an increase in surface area, this loss will have an exponential growth (Dahl & Rinvik, 2010, p. 216).

In Scandinavia the number of osteoporosis related fractures after menopause for women, have doubled in the last 50 years. This increase in fractures is higher than seen in any other place in the world (Sand et al., 2014, p. 304). Since it is widely acknowledged that the body, including the skeletal structures, adapts to strain, it can be assumed that mechanical load may improve bone mineral density (Dahl & Rinvik, 2010, pp. 216–217).
Based on this information, this study will investigate if strength training may have an effect on BMD in healthy postmenopausal women. The reason for selecting healthy women is because underlying conditions may affect bone mineral density and/or bone health in general, either because of the illness itself, treatment and medication, and/or the ability to perform exercises.

Method

For this literature study we used the search engines PubMed, Oria and Google Scholar, where we used a combination and/or variations of the search words *strength training/resistance training/weight training, bone mineral density/bone mineral content* and *postmenopausal women* with the specific exclusion of search words such as *osteoporosis, breast cancer* and *systematic review*. This produced a total result of 65, 532 and 6350 hits respectively, from which a manual search was done to select the most relevant articles. This selection process was done based firstly on the relevance of the title, then the relevance of the abstract. After the first couple of pages of hits in both Oria and Google Scholar, the titles turned less and less relevant, with studies done on training methods without relevance for this thesis, animals, and studies on bone health in men. In addition to the manual search, we also sourced for articles in the list of references provided in Wolff's meta-analysis from 1999. The search was concluded when 8 relevant articles were found.

In addition to the previously stated search words, we had a set of inclusion and exclusion criteria. The inclusion criteria, *healthy women*, was used to eliminate other health related causes for bone loss. Further, the study had to have at least one strength training group, and all the studies had to use a DEXA-scan (Dual-Energy X-ray Absorptiometry) to measure BMD both at baseline and at the end of the study. Additionally, the studies had to be written in either English or Norwegian.

As for the exclusion criterias, the main criterias were studies done on men, as they don't experience menopause, underlying health conditions for reasons listed previously, animals and studies done exclusively on endurance training. Additionally, we excluded secondary literature, as our main priority were clinical studies, primarily intervention studies and controlled trial studies.

Inclusion criteria	***Exclusion criteria***
Healthy women	Males
Strength training	Exclusively endurance training
BMD measured before and after	Underlying health conditions
DEXA-scan	Secondary literature
English or Norwegian	Animals

Table 1: *Inclusion and exclusion criterias*

Results

Study	**Study design**	**Type of training**	**Population (*n*) and distribution***	**Age (± SD) in years**	**Duration**	**Results**
Balsamo et al., 2013	CSS	Strength (ST) Weight-bearing aquatic exercise (Aqua)	*n*=63 - ST= 15 - Aqua=22 - CON=26	ST=51,4 (±2,7) Aqua=54,5 (±3,3) CON=52,0 (±3,3)	Former training experience: ST=4,5 (±2,0) years Aqua=4,2 (±2,2) years	Higher BMD on all measured sites for both ST and Aquatic compared to CON. No difference between ST and Aquatic.
Brentano et al., 2008	RCT	Strength training (ST) Circuit training (CT)	*n*=28 - ST=10 - CT=9 - CON=9	Postmenopausal women, specific ages not presented	24 weeks	No significant difference in BMD in any of the groups.
Chow et al., 1987	RCT	Aerobic exercise (AE) Aerobic and Strength (AS)	*n*=48 - AE= 17 - AS= 16 - CON= 15	AE=56,7 (±0,8) AS=55,8 (±1,0) CON=56,3 (±0,9)	1 year	Significantly higher BMD for both exercise groups. No significant difference between the two exercise groups.
Cussler et al., 2003	Intervention study	Strength training (ST)	*n*=140 - HRT=70	44-66	1 year	Positive, site-specific correlation between weight lifted and BMD, especially between weighted squats and BMD in the femur trochanter.
Hartard et al., 1996	CT	Strength training (ST)	*n*=31 - ST=16 - CON=15	ST=63,6 (±6,2) CON=67,4 (±9,7)	6 months	The control group experienced a significant loss of BMD in the femoral neck, otherwise no significant change in BMD in either group.
Kerr et al., 1996	Intervention study	Strength training (ST) Resistance endurance training (RE)	*n*=56 - ST = 28 - RE =28	ST= 58,4 (±3,7) RE = 55,7 (±4,7)	1 year	BMD increased for the strength group. Peak load seems more important than number of load cycles.

Ryan et al., 1998	Intervention study	Strength training	*n*=27	62 (±1)	16 weeks	No significant change in BMD, neither increase nor decrease.
von Stengel et al., 2007	Intervention study	Strength training (ST) Power training (PT)	*n* = 46 - ST = 24 - PT = 22	ST= 59,0 (±3,8) PT= 57,4 (±3,6)	2 years	Power training seems to be superior to strength training for BMD.

Table 2: *Characteristics of the selected studies. Abbreviations are as follows: CSS = cross sectional study, CT = controlled trial, CON = control group, HRT = hormone replacement therapy, RCT = randomised controlled trial, 1RM = 1 repetition maximum.*
**Population at end of study,* n *with dropouts excluded.*

Result summary

Improved BMD

The majority of studies on this topic appear to find evidence that strength training improves BMD in postmenopausal women. Balsamo et al. (2013) found that after exercise, subjects in the strength training group had significantly higher BMD than subjects in the control group in both the total body and the site's femoral neck and lumbar spine. The study included an aquatic weight-bearing exercise group in addition to a strength and control group. At the lumbar spine, total hip and total body, the measured BMD in the aquatic group was significantly higher than in the control group. There were no significant differences in BMD between the aquatic- and strength groups at any of the sites assessed. Chow et al. (1987) discovered that strength training improved bone density (calcium bone index) when compared to the control group. The study investigated the effects of aerobic exercise, aerobic and strengthening exercise, and no exercise on BMD after a year. After a year, both the aerobic exercise and the aerobic and strengthening exercise groups had significantly higher BMD than the control group. There was no significant difference in BMD between the two exercise groups. Chow et al. (1987) concluded that exercise over all can prevent loss of BMD in postmenopausal women.

Whereas Balsamo et al. (2013) and Chow et al. (1987) investigated the difference between strength training and control groups, Cussler et al. (2003) investigated the relationship between weight lifted and BMD, and Kerr et al. (1996) the difference between one strength trained limb, and one control limb in the same subject. Cussler et al. (2003) found a linear relation between total and exercise specific weight lifted and BMD. The weight lifted in the weighted march correlated significantly with the total body BMD. They found that weighted squats had the strongest correlation with BMD at the femur trochanter, while back extensions had the weakest. As a result, they concluded that the effect of squats on BMD at the femur trochanter indicates that this is a site-specific targeted response. Further Cussler et al. (2003) also found a link between femur trochanter change and the military press, where the muscle targeting is indirect but there is load occurring at the site.

In the study Kerr et al. (1996) conducted, the subjects were assigned one exercise limb, and one non-exercise limb. Then they were further randomly assigned into one resistive endurance group, and one strength training group. The strength group had a high load, low repetition regime while the endurance group had a low load, high repetition regime. For the strength group, the study showed a significant increase in BMD in the exercise limb compared to the non-exercise limb at the trochanteric hip site, the intertrochanteric hip site, and Ward's triangle. For the endurance group the study found no significant difference in BMD at these sites. Kerr et al. (1996) concludes that high load and low repetition is beneficial for BMD in postmenopausal women. They also found that a greater increase in muscle strength might correlate with a greater increase in BMD. With these findings, both Kerr et al. (1996) and Cussler et al. (2003) support the theory of a site specific response and conclude that load is more important than the number of repetitions.

No change, or loss of BMD

Although multiple studies (Kerr et al., 1996; Cussler et al., 2003; Balsamo et al., 2013; Chow et al., 1987) have concluded that strength training improves the BMD in postmenopausal women, there are also studies that did not find an increase in BMD. This is not necessarily a negative outcome, as simply maintaining BMD or slowing the decrease is favourable.

Hartard et al. (1996) investigated if systematic strength training could increase muscle strength and counteract loss of BMD in postmenopausal women, with two training sessions per week. The subjects participating in the strength group trained systematically, with an aim to improve maximum strength. In their study, Hartard et al. (1996) found no significant difference between the BMD in the strength training group and the control group after the 6-month observation period. The only difference found between the two groups were at the femoral neck, where the BMD fell significantly for the control group and did not change for the training group. They concluded that no increase in BMD was to be expected after a period of just 6 months. However, while the subjects of the strength training group did not experience an increase in BMD, they did not experience a decrease either. This implies that the method of training may be effective in maintaining BMD (Hartard et al., 1996).

Another study, done in 1998 by Ryan et al., did not find any evidence of strength training neither increasing nor decreasing BMD in postmenopausal women. They examined the effect of a total body resistive training program on BMD in 27 postmenopausal women. After 16 weeks of a full body strength training program, the BMD did not change significantly at any of the sites. Although Ryan et al. (1998) did not find any change in BMD, he found evidence that body weight was significantly associated with BMD at the lumbar spine and greater trochanter, but not associated with BMD at femoral neck or Ward's triangle. The study also found that initial muscle strength correlated with BMD, as the strength in several exercises correlated directly with BMD at the sites that experienced load during the specific exercises. Since no change in BMD was observed, Ryan et al. (1998) concluded that a full body strength training program may prevent negative health outcomes associated with age-related loss of BMD. This positive effect on health is based on maintaining BMD, and also improving strength in postmenopausal women (Ryan et al., 1998).

von Stengel et al. (2007) looked at the different effect strength- and power training had on BMD in postmenopausal women. The only difference between the exercise protocol for the two groups was the velocity at which the exercises were performed at. The strength group did the exercises with a 4 second concentric and a 4 second eccentric scheme, while the power group did the concentric part of the exercise as fast as possible and the eccentric part slowly at 4 seconds. After both 1 and 2 years, the BMD was measured using a Dexa scan. The BMD were measured at the sites lumbar spine, proximal femur (total hip and subregions) and the forearm. The results from the study do favour power training over strength training in some capacity. The results from the lumbar spine show a significant loss of both BMD and surface area in the subjects who participated in the strength group, while there was no significant change in the power training group. These differences between the groups were significant for both area and BMD. The results from total hip, femoral neck and trochanter also show a significant loss of BMD in the strength training group and no significant change in the power group compared to baseline, but for these sites the in-between group differences were not significant (von Stengel et al., 2007).

Brentano et al. (2008), investigated the difference in effect strength training, circuit weight training (low intensity, high volume, short rest), and no training had on BMD in postmenopausal women. BMD were measured at the start and end of the 24-week training program. The following five sites were measured: lumbar spine, trochanter of femur, intertrochanteric hip site, femoral neck, and Ward's triangle. The measurements did not show any significant changes in BMD at any of the sites, nor any significant difference between the groups. However, it is still worth mentioning that there was an insignificant difference. The strength training group had a small increase, and the circuit group a small decrease in mean BMD compared to their respective baseline measurements. Although the study showed no significant differences, Brentano et al. (2008) concludes that strength training may have a better effect. They point out that other studies with similar training periods have shown similar results, but often with some site-specific differences. This study used a linear periodized training program with a 2-month period of high load. They suggest that this periodization gave too short of a high load period, and they therefore recommend a non-periodized, high intensity program (Brentano et al., 2008).

Discussion

In this study, the relation between strength training and bone health in postmenopausal women were investigated. The study investigates if there is any evidence that strength training effects the BMD in healthy postmenopausal women. The general consensus according to these articles seems to be that strength training has, if not a positive effect, then at least a limiting effect on the negative consequences menopause have on bone mineral density.

Time period

Generally, it seems the studies that found a positive effect of strength training on BMD have a longer study period than the studies that did not find an effect. The four studies mentioned first in the result summary, were all conducted over a period of at least 1 year. Chow et al. (1987), Cussler et al. (2003), and Kerr et al. (1996) all used exercise protocols over a period of 1 year, and measured the BMD before and after intervention. In the study done by Balsamo et al. (2013), the participants trained for a minimum of 1 year prior to the study and the mean years of prior strength training experience were 4,5 (± 2) years.

The studies done by Brentano et al. (2008), Ryan et al. (1998) and Hartard et al. (1996) used study designs where the time period was 6 months or shorter. These studies had a time period of 24 weeks, 16 weeks and 6 months respectively. All of these studies discuss that the time period used may have been too short to show a significant change in BMD. Hartard et al. (1996) states that "The bone density increases more when the training period lasts longer[...]”, and concludes that strength training may have to be done all year around, for the rest of the individual's life, since BMD decreases after training is stopped.

von Stengel et al. (2007) had the longest time frame at 2 years. The results show a decrease in BMD for the defined strength group, and no change for the power group. This indicates that for this time frame, a higher load is beneficial. The results do also show that the decrease for the strength group was similar for both years, and that for the power group the effect was most prominent after the first year. They discuss that this is due to the adaptations to changes in the mechanical environment, based on the principle of cellular accommodation in bone tissue (von Stengel et al., 2007). After the first year of training the subjects may have adapted to the new training stimuli. This is also in line with the training principle of diminishing returns, which states that as the body adapts to increased physical demands, the benefits of exercise will gradually diminish (Hoffman, 2014, pp. 94–96). Therefore, it is safe to assume that the effect strength training can have on BMD in postmenopausal women, may only appear after an extended period of training.

Muscle strength, body weight and BMD

Some studies have found evidence of a correlation between muscle strength and BMD at specific sites when measuring (Kerr et al., 1996; Ryan et al., 1998). Additionally, Ryan et al. (1998) found that body weight correlated with BMD at baseline, which may be in line with the theory of tissue adapting to mechanical load. A higher body weight will add additional stress on the bones, and add load when doing mundane tasks like walking up and down stairs compared to an individual with a lower body weight.

Site specific effect

When looking into the studies that did find that strength training had a significant effect on BMD in postmenopausal women, there seems to be a correlation between how much weight was lifted in specific exercises and the effect on BMD at the site where load was the greatest (Cussler et al., 2003; Kerr et al., 1996; Ryan et al., 1998). Ryan et al. (1998) found a significant association between body weight and BMD at the greater trochanter. The study also showed a correlation between the subjects’ initial strength in leg press and the BMD at L2-L4, the femoral neck, Ward’s triangle and greater trochanter. Similar results were found between the initial strength on the chest press and the BMD of the lumbar spine, femoral neck, Ward’s triangle, and greater trochanter. The study did not find a significant correlation between the strength on the leg extension or latissimus pull down, and the BMD of the femoral neck, Ward’s triangle, and greater trochanter (Ryan et al., 1998). This indicates that the exercises that stimulate load and compression to the bones have a better effect than nonspecific exercises or exercises that don't stimulate compression to the bone.

Methods of strength training

Several of the studies done on the effect strength training may have on BMD in postmenopausal women, do also look at other training methods, in addition to traditional strength training. The training methods used can also be described as strength training, although they are not the traditional method of lifting weights and/or using exercise machines.

Kerr et al. (1996) investigated the effect of resistive endurance training on BMD in addition to strength training. The groups were also described as following a high load, low repetition regime (strength group) and a low load, high repetition regime (endurance group). The study did not find any difference in BMD between the exercising and non-exercising limb after the training period for the endurance group at the hip sites, but a significant difference at the radius. The results from the strength group did show a significant increase in BMD at the hip sites in the exercise limb compared to the non-exercising limb after the same time period of exercise. This indicates that the high load, low repetition regime is more effective in maintaining or improving BMD in postmenopausal women, compared to the low load, high repetition regime that were used by the endurance group.
Balsamo et al. (2013), Brentano et al. (2008), and Chow et al. (1987) also investigated other forms of training, in these cases the alternative training showed similar results as the strength training. For these studies the results indicate that aquatic strengthening exercise, circuit training and aerobic exercise have similar effects on BMD as the strength training exercise used in the same studies (Balsamo et al., 2013; Brentano et al., 2008; Chow et al., 1987).

von Stengel et al. (2007) had a power training group in addition to a strength training group, this group showed no difference in BMD after the training period, where the strength training group showed a significant loss of BMD. Based on the results, especially in the lumbar spine, the power training regime seems to be superior to the strength training regime. Provided that the participant is able to perform the power training, this appears to be an effective form of exercise if the aim is to improve BMD and daily function in postmenopausal women.

Results from the studies finding similar effects from other methods of strength training may indicate that any training is better than no training. This can also support that the most important factor in slowing down or stopping the natural postmenopausal loss of BMD, increasing or maintaining BMD, is load regardless of how this load is achieved.

Differences in load

There seems to be evidence that the load achieved during exercise is more important than the method of training to achieve this load. Studies investigating the relationship between exercise and BMD, have found evidence that load on the bone achieved during activities and exercise has a positive effect on improving BMD (Heinonen et al., 1993).

From the studies used in this thesis, we can see a trend where high load is most effective in improving or maintaining BMD in postmenopausal women. In addition to this there seems to be an effect on BMD in the subjects doing load bearing exercises, both with high load and with lower load. Chow et al. (1987) found that their aerobic exercise group did show a significant improvement in BMD compared to the control group after the training period. This group was not defined as doing strengthening exercises, as the aerobic and strengthening exercise group were. During the aerobic exercise the exercises performed were walking, jogging and dancing. These exercises do not qualify as strength training in the traditional way, but one can assume that the load achieved during the exercises contributed to the positive effect on BMD found. von Stengel et al. (2007), found a loss of BMD in the defined strength training group and no change in the power training group. From the results in this study, one can see that the power training group achieved significantly higher load, compared to the strength group. von Stengel et al. (2007)'s findings support that load seems to be an important factor in maintaining and increasing BMD.

Conclusion

After reviewing the chosen studies on the effect of strength training on BMD in healthy postmenopausal women, it seems reasonable to conclude that strength training is effective, both in slowing the natural loss of BMD, and maintaining and possibly improving the BMD. When looking at the different forms of strength training, and the different exercise protocols, it seems that the most important factor when aiming for a positive effect of the training is mechanical load parallel to the trabeculae. This can both be seen in the results when compared to the different exercise protocols, and in the trend seen in results showing a site-specific effect between exercises and BMD measured at different sites. From the studies it can also be concluded that to get a positive effect, the training period has to be progressive over a longer period of time. With this in mind we can conclude that any exercise is better than no exercise when aiming to maintain or improve BMD, or slow down the natural loss of BMD in postmenopausal women. Although any exercise is better than no exercise, it seems that the higher the load one can achieve, the better the effect at the site of load. One would therefore recommend postmenopausal women to exercise regularly, with focus on peak load achieved if the aim is a positive effect on BMD. Different forms of strength training will therefore be good alternatives of exercise for postmenopausal women.

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