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Effectiveness of resistance training on bone mineral density in post-menopausal women with osteoporosis

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SUMMARY

AUTHORS' CONTRIBUTION: (A) Study Design · **(B)** Data Collection. **(C)** Statistical Analysis · **(D)** Data Interpretation · **(E)** Manuscript Preparation · **(F)** Literature Search · **(G)** Funds Collection

Poor bone mineral density is associated with aging. However, menopause in females promote decline in overall bone mineral density and hence lead to the higher risk of bone fracture. Strength training is considered as effective non pharmacological intervention in this regard.

To assess the effect of resistance training on bone mineral density in post-menopausal women with osteoporosis. Total 30 female participants were recruited in this study. 15 females were included in strength training group (Group 2) and remaining 15 in control groups (Group 1). 15 women in resistance training group completed total nine months' sessions of strength training as it was scheduled for at least 3 times a week. Dietary intake and blood hormonal profile were measured before and at the end of the strength training session. BMD of spine, distal wrist and femoral neck were also examined before and after the strength training.

We did not observe any significant difference in hormonal profile before and after strength training in group 2. Bone mineral density of distal wrist and femoral neck in group 2 were not statistically significant in strength training group when compared with control group. However, spine BMD was improved and observed significant in resistance training group.

We can conclude that resistance training is useful non pharmacological intervention for the post-menopausal women with osteoporosis. As bone mineral density declines after menopause in women so current strength training modality may be helpful in the overall bone health of women with menopause.

Keywords: Bone mineral density; Post-Menopausal women; Resistance training; Osteoporosis

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INTRODUCTION

Osteoporosis is a condition characterized by weakened bones and an increased likelihood of fracture. As a result of osteoporosis-related fragility fractures, life expectancy decreases, death rates rise, and economic expenses skyrocket. The number of men and women at high risk of osteoporotic fractures in 2010 is anticipated to quadruple by 2040, according to a research, highlighting the critical nature of addressing this disease [1].

Load-bearing exercise intervention is advised as a non-pharmacotherapeutic way to increasing Bone Mineral density (BMD) in the prevention and treatment of osteoporosis. Normal load activities, such as weight training, have been found to increase Bone Mineral Density (BMD), and successful tactics have been explored from a variety of angles, including training type, frequency, and combination [2,3].

There are findings connecting the amount of weight used in resistance training to the subsequent Bone Mineral Density (BMD), making load quantity an essential consideration in resistance training. High-load resistance training (HLRT) significantly increased BMD in the lumbar spine but not in the femoral neck in a meta-analysis of 14 randomized control trials investigating the impact of HLRT on BMD in postmenopausal women. Some research suggests that HLRT is more successful than traditional resistance training in strengthening the lower limbs, and that it is the most efficient method of its kind for people of any age. Recent research has linked a reduction in muscular strength to an increased risk of bone fracture, suggesting that HLRT's ability to boost both muscle strength and BMD at once might make it a useful strategy for preventing fragility fractures [4].

PROBLEM STATEMENT

Unfortunately, inconsistent findings have been found in conventional narrative reviews of the effects of increasing resistance training on Bone Mineral Density (BMD). Some studies have shown a possible favorable impact of progressive resistance exercise on Bone Mineral Density (BMD), whereas other studies have found a positive effect of progressive resistance exercise [5-7]. Considering that intervention research on the benefits of resistance exercise on BMD in adults have shown less than overwhelmingly favorable findings, these inconsistencies are not unexpected.

The goal of this study is to assess the evidence for the benefits of weighted exercise on Bone Mineral Density (BMD) in postmenopausal women with osteoporosis.

AIMS OF THE STUDY

Following are the aims of the study:

- To assess the relationship between Bone Mineral Density (BMD) and strength training in post-menopausal women with osteoporosis.
- To investigate whether strength training is effective to improve bone mineral density (BMD) in post-menopausal women with osteoporosis.

Questions of the study

Following are the questions of the study:

- Is there any relationship between Bone Mineral Density (BMD) and strength training in post-menopausal women with osteoporosis?
- Is strength training being effective to improve Bone Mineral Density (BMD) in in post-menopausal women with osteoporosis?

Significance of the study

In order to maximize bone density in young population and avoid bone loss in old age, regular physical exercise has been proposed as a nonpharmacologic intervention. Aerobic exercise improves Bone Mineral Density (BMD) in the lumbar spine and hips of postmenopausal women, according to recent meta-analyses. Resistance training is another sort of exercise that may be beneficial. Most people have access to resistance training since it is a low-cost, nonpharmacologic intervention. Resistance training has several health benefits for both men and women of adulthood, including improved bone density, leaner bodies, and stronger muscles [8].

LITERATURE REVIEW

Osteoporosis is a degenerative condition of the skeleton that causes the bones to become weak and brittle and increases the likelihood that they will break. Radiographs of people with osteopenia show that their bones have a lower mineral content than usual, with a BMD that is below normal but over the osteoporosis cutoff. Osteoporosis affects 30% of women worldwide after menopause, according to the WHO [9].

When estrogen levels drop after menopause, causing bone resorption to rise without a corresponding increase in bone production, a condition known as postmenopausal or Type I osteoporosis occurs. This helps speed up the process of bone depletion. Hip, vertebral body and wrist fractures are the most frequent results of osteoporosis [10].

Type II osteoporosis, which affects both sexes of elderly people, is characterized by a steady decline in bone mineral density (BMD) and affects both trabecular bone and cortical bone which is linked with hip fractures [11].

Osteoporosis may be prevented or treated using a variety of pharmaceuticals, including Hormone Replacement Therapy (HRT), bisphosphonates, calcitonin, and selective estrogen receptor modulators [12]. These drugs have a high price tag and come with the risk of dangerous side effects. Alternatives or supplements to pharmacological treatment may include increasing calcium intake, quitting smoking and alcohol use, and engaging in strength training and weight-bearing/ loading exercises [10].

METHODOLOGY

Total 30 post-menopausal women with osteoporosis were recruited for this study. The Department of Orthopedics at Aster Al Raffah Hospital, Oman had conducted this study from January 2022 till February, 2023.

Patient recruitment

Fifteen ladies signed up for the resistance training session. Fifteen females served as a control group and were not part of strength training or any other kind of intense physical activity during the study's 9-month duration. Throughout the exercise training programs, more women were recruited for the weight-training group to compensate for the inevitable high dropout rates.

This study was approved by the departmental ethical committee and informed consent forms were collected from all participants. Each participant filled out a health questionnaire including their gynecological history, osteoporosis risk, dietary habits, and exercise routines. Participants were between the ages of 2 and 6 years postmenopausal and had not had any treatment for bone metabolism. Conditions that may affect calcium absorption were also ruled out, such as diabetes, hyper- or hypoparathyroidism, hypo- or hyperthyroidism, Paget's disease, Cushing's syndrome, and immobilization-induced or thyrotoxicosis-induced osteoporosis.

None of the research subjects had engaged in strenuous physical training in the prior six months. Everyone who took part had never done anything like weight training before.

Strength training

The weight training group were trained for 9 months, three times a week. Every hour-long session included a 10-minute warm-up, 30 minutes of weight training, and a 10-minute cool-down.

The training plan was designed in part to provide a localized muscular overload in the areas of the body where BMD was measured.

The individuals could easily complete 12-15 repetitions of each exercise with the modest weights used at the beginning of their training to ensure their safety and teach them how to lift properly. Each participant completed one set of 10-15 Repetitions Maximum (RM) for each lower body exercise and one set of 10-12 RM for upper body training during their training session after acclimating to the weight-lifting procedures for 3 weeks. An initial work load of 50% to 60% of one repetition maximum was used. The goal was to increase program adherence; hence a relatively modest level of intensity was chosen. Training weight was raised as necessary until only 15 RM (lower body) and 12 repetitions maximum

[13] (upper body) were attainable for each participant. The sessions were all observed by the researchers.

Maintaining regular exercise levels was stressed to both the weight-training and control groups. Both strength trained and control groups were inquired and monitored at certain intervals to verify that they were following the protocol.

Bone mineral density status

Bone density was evaluated initially and again after 9 months. Single-photon absorptiometry (Nuclear Data I100, Schaumburg, IL) was used to assess the Bone Mineral Density (BMD, g/cm^2) of the nondominant forearm's radius as well as ulna. The BMD in the distal forearm was determined by averaging two scans taken beyond the point where the radius and ulna are separated by 5 mm. Every day, scans of a calibration standard were performed.

The L2-4 of the spine and right femur were analyzed for bone mineral content by dual-photon absorptiometry (Lunar Radiation Corporation bone mineral analyzer Model DP3, Madison, WI). The right femur was scanned starting at the lesser trochanter and moving proximally to the head of femur.

The femoral neck area of interest was typically 1.5 cm wide by 6.0 cm long, reaching into soft tissue on both sides of the femoral neck. The angle of this area was centrally located and perpendicular to the neck of femur. Each individual had a printed copy of the picture of the scanned area to use for comparison during subsequent scans. The central lumbar region was scanned, beginning at the top of L2 and ending at the bottom of L4. A scanned copy of the spinal bone was created to ensure uniformity between subsequent lumbar scans on the same individual. The region size of L2-4 was employed as a benchmark to ensure consistency across scans.

Accuracy of single- and dual-photon absorptiometry methods over the short term was assessed in a study including six female participants. Each person was scanned three times at weekly intervals. For the lower arm, the coefficient of variation was 2.5%. The femoral neck and lumbar areas had reproducibility of +1.5% and +1.6070, respectively. Throughout the course of the investigation, the dual-photon absorptiometer (Hologic X-caliber; Hologic, Waltham, MA) was used to scan a lumbar spine phantom at regular intervals of 6-month. Stability over time was around + 0.3%.

Sample collection

Before and after each participant's nine months of training, blood was taken from them. Between exercise sessions, blood samples were collected at least 8 hours apart. Blood parameters including calcium, phosphorus, and magnesium were examined for pre and post assessment of the session, and each participant's food consumption was meticulously observed for 4 days before and after the session. However, other tests were performed before and after the session, including those for the gla protein or osteocalcin, ALP, PTH, FSH, Estradiol, serum Vitamin D level, etc.

Evaluations of force

The greatest number of times that the leg press, bench press, and trunk extension could be performed was discovered by trial and error. The one repetition maximum for each exercise was tested twice, and the results were compared. The bench press had an intraclass correlation value of 0.91, the trunk extension 0.89 and the leg press 0.84. Measurements of strength were taken initially and after nine months strength training.

Data analysis

All study characteristics were compared at baseline in strength trained and control groups using Student's t-test. Maximal strength was measured at baseline and 9 months later, and we conducted repeated-measures analysis of variance following Tukey’s test. Changes in Bone Mineral Density (BMD), hematological parameters, tested hormones and estimated daily calorie intake were compared across groups using analysis of variance and covariance. Statistical significance was determined at the $p<0.05$ level. The data are presented as a mean and standard error of mean.

RESULTS

Tab. 1. lists the normal ranges for serum variables. Vitamin D3 was the only hormone which was found statistically different in resistance training group and control group. Among calcium, magnesium and phosphorus, only phosphorous level was significantly different between the weight training and control group with the p-value of 0.02. The age and weight of control group and weight resistance group were also statistically significantly different i.e. p-value of 0.001 and 0.003 respectively.

The average shifts in serum biochemical indicators are shown in **Tab. 2.** from baseline to 9 months. Bone-related indicators (osteocalcin, parathyroid hormone and alkaline phosphatase showed no significant group differences. Throughout the course of the study's 9 months, Follicle-Stimulating Hormone (FSH) levels were consistently high. The 9-month change in FSH was similar across groups. After 9 months, all individuals' estradiol levels were below the assay's detection limit of 20 pg/ml.

Tab. 3. displays the average values for femoral neck bone mineral content, spinal bone mineral content, and distal bone mineral content of distal wrist. There was no statistically significant difference in the mean bone mineral density at the three skeletal locations at baseline between the groups. At study's end, the weight-training group showed a statistically significant increase in spinal bone mineral density when compared with control group ($p=0.001$). There was no statistically significant difference in the rate of change in femoral neck BMD or distal wrist BMC between the groups.

DISCUSSION

Results from this research show that weight training may improve bone mineral density status in postmenopausal women who have low estrogen levels. This is the first research to find a beneficial impact of weight training on bone mineral density in the spine. The decrease in lumbar BMD shown in our control group is prevalent throughout the early years of menopause in

Tab. 1. Baseline information of study participants.

Baseline Details	Resistance Training Group (n=15) Mean ± SEM	Control Group (n=15) Mean+SEM	p-Value
Age (Years)	52 ± 0.6	57 ± 3	0.001
Height (cm)	159.2 ± 2.1	164.2 ± 2.5	>0.05
Weight (Kg)	72.5 ± 2.5	64.2 ± 1.9	0.003
Menopausal Years	4.4 ± 0.5	4.2 ± 0.6	>0.05
Calcium (mg/day)	912 ± 66	789 ± 51	>0.05
Phosphorous (mg/day)	1289 ± 70	998 ± 82	0.02
Magnesium(mg/day)	290 ± 70	252 ± 74	>0.05
ALP (IU/L)	81.2 ± 4.9	90.2 ± 4.5	>0.05
Osteocalcin (ng/ml)	5.5 ± 0.4	5.3 ± 0.2	>0.05
Vitamin D3 (ng/ml)	25.3 ± 1.2	19.8 ± 2.5	0.001
PTH (pg/ml)	48 ± 2.8	49 ± 1.9	>0.05
FSH (IU/L)	90 ± 4	93 ± 6	>0.05
Estradiol (pg/ml)	<20	<20	>0.05

SEM= Standard Error of Mean, ALP= Alkaline Phosphatase, PTH= Parathyroid Hormone and FSH= Follicular Stimulating Hormone.

Tab. 2. Pre and post session hormonal difference in resistance training group and control group.

Hormonal Profile	Resistance Training Group		p-Value	Control Group		p-Value
	Before Session	After Session		Before Session	After Session	
	Mean ± SEM	Mean ± SEM		Mean ± SEM	Mean ± SEM	
ALP (IU/L)	81.2 ± 4.9	84.2 ± 3.3	>0.05	90.2 ± 4.5	89.2 ± 3.3	>0.05
Osteocalcin (ng/ml)	5.5 ± 0.4	5.3 ± 0.3		5.3 ± 0.2	5.2 ± 0.4	
Vitamin D3 (ng/ml)	25.3 ± 1.2	28.3 ± 1.5		19.8 ± 2.5	21.2 ± 2.2	
PTH (pg/ml)	48.2 ± 2.8	49.3 ± 2.8		49.6 ± 1.9	51.1 ± 0.8	
FSH (IU/L)	90.5 ± 4.5	95.5 ± 3.2		93.2 ± 6.2	94.2 ± 3.6	
Estradiol (pg/ml)	<20	<20		<20	<20	

SEM= Standard Error of Mean, ALP= Alkaline Phosphatase, PTH= Parathyroid Hormone and FSH= Follicular Stimulating Hormone.

Tab. 3. Pre and post session Bone Mineral Density (BMD) status in resistance training group and control group.

Bone Mineral Density (g/cm^2)	Resistance Training Group		Resistance Training Group		p-Value
	Before Session	After Session	Before Session	After Session	
	Mean ± SEM	Mean ± SEM	Mean ± SEM	Mean ± SEM	
Distal Wrist	0.929 ± 0.020	0.919 ± 0.015	0.894 ± 0.020	0.909 ± 0.015	>0.05
Spine	1.131 ± 0.021	1.139 ± 0.023	1.111 ± 0.05	1.089 ± 0.052	0.001
Femoral Neck	0.830 ± 0.022	0.817 ± 0.018	0.794 ± 0.055	0.785 ± 0.032	>0.05

women. It was found that, on average, women lost an estimated 6.5% of their spinal bone mass every year in the first couple of years after menopause [14]. The increased rate of bone loss in the spine during menopause is not maintained and actually slows down as time passes after menopause [15].

There was no significant difference between the groups in terms of changes in estradiol, FSH, parathyroid hormone except 25-hydroxyvitamin D or nutritional consumption except phosphorous. As a result, discrepancies in lumbar spine structure across groups are unlikely to have resulted from variation in hormonal state or variances in the ingestion of dietary pattern essential to appropriate bone function or metabolism.

Exercise training has been shown to improve or maintain bone mineral density of lumbar bone in several investigations of women who were at their menopausal age. An 8-month duration study of anaerobic and aerobic exercise preserved lumbar bone mineral density (3.5+1.6%; compared to a -2.7+1.3% loss in the control group) in people with a history of Colle's fracture [16].

There was no discernible change in femoral neck bone mineral density due to the weight training regimen. It was postulated that areas of the skeleton where bone of trabeculae predominated would be the one to adapt to a stimulus such as weightlifting. When compared to cortical bone, another type of bone in the skeleton, trabecular bone has a higher metabolic activity [17]. A higher percentage of bone with a lower metabolic level may explain the "insensitivity" of this area to the weight-training intervention. Perhaps nine months wasn't long enough to detect subtle changes in the environment.

In order to prevent bone loss, it has long been recommended that women participate in weight-bearing activities. Though beneficial for health as a whole, there is less evidence that it also improves bone health. One recent study indicated that a walking program lasting 12 months did not slow the decline in spine mineral density seen by postmenopausal women. Both the walkers and the sedentary controls had a considerable loss in spinal trabecular mineral density (5.6+1.4% *vs.* 4.0+1.2%, respectively) [18].

Strain levels over the threshold value i.e. weightlifting may affect bone remodeling. Bone resorption occurs at a higher rate than bone production throughout the postmenopausal period of bone remodeling [19]. There is some evidence that weight training may increase bone growth in young men by affecting hormones that control calcium and the osteocalcin or gla protein found in bones. A study was conducted by comparing a group of young adult male weight trainers with a group of age-matched non-weight trainers. Serum gla protein was found to be greater in the exercisers (39+5 ng/ml *vs.* 24+2 ng/ml) and 1,25-dihydroxyvitamin D was found to be higher in the exercisers (40+2 pg/ml *vs.* 29+2 pg/ml). It was speculated that weight training might improve bone growth and increase accessible calcium, both of which would be helpful to the skeleton [20].

In contrast, postmenopausal women in our study showed no changes in serum gla protein. Similar to previous study findings which reported an increase in lumbar BMC after a 9-month training program but observed no change in this protein [21]. This indicates that the mechanisms responsible for mediating bone responses to exercise training may vary somewhat from one group to the next. There needs to be more study done on this aspect.

Our recruited participants of postmenopausal women benefited from a strength-training regimen of moderate intensity. However, studies on the impacts of strength training on premenopausal women have shown mixed results. Rockwell and colleagues showed negative effects of weight training on BMD of lumbar region in their recruited premenopausal women [22], whereas Gleeson and colleagues [23] observed strength training to be related with improvement in the BMD of lumbar region. Inconsistencies in the effectiveness of weight training in positively altering bone state may be attributable to subjective characteristics along with the designs of exercise programs. Determining probable processes related with changes in bone density and outlining a resistance training "prescription" for optimum health of bone in premenopausal and postmenopausal women are both important areas for future study.

CONCLUSION

In conclusion, our study participants of postmenopausal women who participated in resistance training had a slower rate of reduction in lumbar BMD. As the femoral neck has a larger percentage of cortical bone, which is less metabolically active than trabecular bone, weight training may not have had an effect on BMD there.

FUTURE DIRECTIONS

Additional research into this kind of exercise is warranted as a viable alternative or supplement to the conventional weight-bearing exercises now prescribed to women to slow the decline in lumbar Bone Mineral Density (BMD) that occurs after menopause.

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