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The Effect of Four Months of Core Stability Training on Femoral Bone Mineral Density and Lower Extremity Muscles Strength in Postmenopausal Women

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Abstract

Background: *Osteoporosis is a skeletal disease associated with a gradual decline of bone density, as well as a characteristic reduction of bone rigidity and an increased risk of fractures. This study aimed to investigate the effects of four months of core stability training on the bone mineral density (BMD) of the femur neck and lower extremity muscles strength in postmenopausal women.*

Methods: *This study was an interventional semi-experimental one designed with a pre-test/post-test approach. Overall, 30 postmenopausal women aged 48 to 58 years were purposefully selected and then randomly divided into two groups of core stability exercise (weight=70.73±12.57 Kg) and control (weight=77.86±7.19 Kg) groups. The participants of the core stability group performed the exercise protocol three times a week for four months. These exercises consisted of five levels, and based on the gradual progress principle, their intensity was gradually increased over the four months during the study. The participants of the control group did not perform any exercise during the study. The BMD of the dominant femur neck was measured by a Dexa device, and the flexor and external rotator strength of the hip was measured by a manual dynamometer. Data analysis was performed applying paired and independent-sample t-test in SPSS23 software. The significant level was set at 0.05.*

Results: *The results of paired samples t-test showed that the BMD of the femur neck significantly increased in the core stability group (Pvalue=0.001) and significantly decreased in the control group (Pvalue=0.045) at the post-test compared to the pre-test. Also in intra-group comparison, the flexor and external rotator strength of the hip significantly were increased in the core stability group (Pvalue=0.001 and 0.001, respectively). While there was not such a significant change in the control group. On the other hand, based on the results of the independent samples t-test, the femur neck BMD (Pvalue=0.007) and the flexor and external rotator strength of the hip (Pvalue=0.001 and 0.001, respectively) significantly increased in the core stability compared to the control group.*

Conclusions: *According to the results, it seems that core stability exercises can be suggested to postmenopausal women as an effective strategy for osteogenic bone behavior and reducing the risk of osteoporosis.*

Keywords: Core stability training, Femur bone mineral density, Lower extremity muscles strength, Postmenopausal women.

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Introduction

Osteoporosis characterized with a prominent loss of bone mass is one of the most common metabolic bone diseases, observed in more than half of women around the age of 50.[1] The disease is one of the major health problems in the world.[2] Bone formation and construction is a continuous process in the body so that bone mass reaches its climax around the age of 30 and then starts a continuous decline. It has been estimated that the number of patients with osteoporosis in the United States will increase from 10 to 14 million by 2020.[3] Among these, postmenopausal women, due to a decrease in estrogen level and having relatively thinner and smaller bones, are particularly prone to a rapid decline in bone mineral density (BMD) and osteoporosis.[4] Bone loss in postmenopausal women is related to the advancing age and has been reported to range from 1.1 to 1.4% per year for the femur neck during the first four to five years after menopause.[5] At the onset of the menopausal age and due to the loss of ovarian function and decreased estrogen production, the loss of BMD increases, which in turn enhances the activity of osteoclasts. In fact, during the first five to 10 years of menopause, women lose 25-30% and 10-15% of their trabecular and cortical bones, respectively.[1]

In recent studies, the prevalence of osteoporosis in Iranian postmenopausal women has been estimated as 32%, and this rate has been 25% for the femur neck. Also, it has been mentioned that half of the Iranian postmenopausal women have a low bone density, which is a significant risk factor indicating a higher incidence of osteoporosis and its associated complications in the future.[6]

Although pharmaceutical drugs have had main roles in preventing and treating osteoporosis, concerns about the risk of long-term use of these agents are increasing.[3] On the other hand, the role of physical activity in boosting skeletal health and bone mass has been proven in multiple studies.[7]

Although exercise is widely recommended as one of the main strategies to prevent the development and reduce the risk of osteoporosis, its effects on bone have been controversial5. Core stability exercises are known as those involved with the body's deep muscles including the spine local muscles, abdominal muscles group, as well as pelvic and hip muscles.[8] The core is the center of the functional kinetic chain which provides proximal stability for distal movement and limbs.[9] Available evidence indicates that skeletal adaptations in response to load are site-specific. So, exercise should contain purposeful activities that either directly (via gravity loading) or indirectly (via muscular stretching on the bone) exert the relevant load on the target bone, for example at the hip.[10] From a functional point of view, the core acts as a link that facilitates the transfer of torque forces between the upper and lower limbs.[8] Therefore, here we assumed that core stability exercises, via the link with lower limbs, can transfer core stability forces to lower limbs and particularly to the femur and in this way increase its BMD.

On the other hand, with the onset of menopause, postmenopausal women's muscular mass and strength decrease with age.[11,12] The results of a study on 44 to 87-year-old women showed that the muscular strength and BMD of upper limbs decreased during the fifth and sixth decades of life while the muscular strength of lower limbs decreased during the sixth decade before a decline in BMD in the seventh and eighth decades.[13] Middleton et al. showed that the changes in the strength positively predicted the alterations of BMD in postmenopausal women, so they concluded that exercise, by increasing the strength, can have an important role in maintaining BMD in postmenopausal women.[14] Considering the above-mentioned and the fact that to our knowledge, there were no similar studies on the issue, and also the priority of preventive rather than therapeutic strategies, the present study aimed to investigate the effects of core stability exercises on the femur BMD and the muscles strength of lower limbs in postmenopausal women.

Materials and Methods

This study was an interventional semi-experimental one designed with a pre-test/post-test approach. The statistical population included all postmenopausal women (with the age of 48 to 58 years and having at least one year passed from menopause) in Zahedan city. For sampling, at first, healthy postmenopausal women attainable and volunteering to participate in the study were invited. Afterwards the Beck physical activity questionnaire and two questionnaires for demographic and clinical (any history for injury) features were distributed among the volunteers. After collecting the questionnaires, those who were not eligible were excluded, and the remaining individuals (n=30) were selected for the research. These subjects were initially asked to sign a written consent form, and after that, they were randomly divided into two groups of core stability exercise (n=15) and control (n=15) applying the rules of group matching (based on age, BMI, and duration of menopause).

Inclusion criteria were the age range of 48 to 58 years, passing of at least one year from menopause, and having no regular physical activities during the past 6 months. Exclusion criteria were smoking, alcohol consumption, taking any drug (e.g. calcium tablets, multivitamins containing calcium and vitamin D) that affects bone metabolism, histories of fracture and surgery, or severe injuries.

The research variables were measured at pre-test (before initiating the core stability exercises) and post-test (following four months of the exercises) phases. The BMD of the dominant femur neck was measured by a bone density scanning device or Dexa device (HOLOGIC, USA). The muscular strength of lower limbs was determined using a manual dynamometer (SPF, China). To fix the target limb and eliminate the effect of the examiner's strength, a stabilizing strap was used for all the subjects. After one sub-maximal repetition in each muscle group, three 5-second repetitions (with 30-second rest intervals) were performed with the maximum isometric strength, and the maximum strength from the three repetitions was recorded and normalized respective to the subject's weight.[15] The normalized value was used for the final analysis. To measure the strength of the hip flexor muscles; the subject was asked to lay on his side on a bed so that the dynamometer fixed to the wall was behind him, and the target limb was above. To fix the pelvis on the table, a strap was placed around it, and a towel was inserted between the subject's thighs. Meanwhile, the subject was trained to place the target limb at zero hip flexion. The other strap which had been used to stabilize the dynamometer fixed on the wall was located at 5-cm to the knee proximal.[16] The subject was asked to keep her toes forward, avoid bending the knee and perform the hip flexion with the maximum contraction. The highest hip flexion strength among three repetitions was recorded (as Kg) and normalized according to the subject's weight. Then the subject was asked to lay on the other side to determine the strength of the opposite hip in the same way. To determine the hip's external rotator strength, the subject was placed on the bed in the prone position so that the hip joint was in a neutral position while the knee joint had a 90-degree flexion. The distal part of the thigh was fixed using a strap, and a towel was used to limit the hip adductor effects. The other limb in a straight position was placed on the bed, and the dynamometer was located at 5-cm above the ankle so that the strap fixing the dynamometer wrapped around the inner ankle. Next, the subject was requested to perform a hip external rotation movement with the maximum contraction by the target foot. The highest external rotation strength of the hip from three repetitions was recorded and normalized according to the subject's weight.[15,16]

In the present study, the exercises were chosen based on the core stability exercises proposed by Jeffrey et al. The protocol was designed to involve the global (superficial and larger) and local (smaller and deeper) muscles with a focus on specialized exercises for the spine proximal and hip distal, retraining the proprioception of lumbar-pelvic area, performing hollowing maneuvers along with multifidus contractions in supine, prone, and sided positions and adding dynamic components to them (limb movements and using a Swiss ball, medicine ball, and dumbbells at higher levels). The exercises consisted of five levels. Level one included static isometric contraction in a fixed position, level two consisted of static isometric contraction simultaneous with a controlled limb movement in a stable environment, level three involved static contraction in unstable (for example an unbalanced surface) and dynamic movements in stable (a fixed surface) environments, level four included dynamic movements in an unstable environment (e.g. body movement on an unbalanced surface), and finally, level 5 consisted of dynamic resistance movements in an unstable environment (e.g. an unbalanced surface).[17] The exercise protocol was performed for four months, three sessions a week (Table1), and during this time, exercise intensity increased based on the gradual progression principle. At first, each exercise at different levels was executed for three sets of 15 seconds, which gradually upgraded to three sets of 45-second at the fourth month.[8,18] Also during the 4 months of the core stability training protocol, the subjects in the control group were asked to perform their usual daily activities and not participate in any sports program.

Table1. Core stability training program

Level	Exercise		Month 1	Month 2	Month 3				Month 4
1	E1: Side bridge E2: Double straight leg lift E3: One leg bridge	Set & repeat (second)	3×15	3×30	3×35				3×45
2	E4: Deed bug E5: Quadruped arm/leg raise		3×15	3×30	3×35				3×45
3	E6: Bicycle crunch E7: Iso crunch on Swiss ball		3×15	3×30	3×35				3×45
4	E8: Swiss ball body-weight wall squat E9: Hamstring curl on Swiss ball		-	-	3×35				3×45
5	E10: Medicine ball exercise on Swiss ball E11: Dumbbell exercise on Swiss ball		-	-	3×35				3×45
					W1	W2	W3	W4	Med:4 kg &
					1 Kg	2Kg	3 Kg	4 Kg	Dum: 2 kg+2 kg

E: exercise, Med: medicine ball, Dum: dumbbell, W: week

The KS test was used to evaluate the normality of the data, and the Levene's test was utilized to assess the homogeneity of variances. Within and between groups (core stability training vs. control) comparisons were conducted by the paired and independent samples t-tests. Statistical analyses were performed in SPSS[23] software. The significant level was set at 0.05.

Results

Physical and anthropometric characteristics of core stability and control groups have been reported in table 2. According to the results of this table, there was no significant difference in age, height, weight, and body mass index of subjects at the beginning of the study between the two groups.

Table 2. Physical and anthropometric characteristics of core stability and control groups

Variable	Core stability group Mean±SD	Control group Mean±SD	Pvalue
Age (year)	53.13±4.01	53.00±4.01	0.928
Height (cm)	158.20±5.05	159.60±5.66	0.481
Weight (kg)	70.73±12.57	77.86±7.19	0.067
BMI (kg/cm^2)	28.37±5.54	30.65±3.30	0.203

According to table 3 and based on the results of paired t-test, a significant increase in BMD of the femoral neck was observed from pre-test to post-test (mean difference=-0.08 g/cm2) in the core stability group (Pvalue=0.001). Also, there was a significant decrease between the pre-test and post-test in the control group (Pvalue=0.045) concerning BMD of the femoral neck. In addition, based on the results of the independent-samples t-test, a significant increase in BMD of the femoral neck was observed in the core stability group compared to the control group (Pvalue=0.007). Also based on the results of paired t-test, a significant increase in strength of flexor and external rotator of the right and left hip (Pvalue=0.001 and 0.001, respectively) was observed from pre-test to post-test in the core stability group. While such a significant change was not observed in the control group (Pvalue>0.05). In addition, the results of the independent-samples t-test showed that a significant increase was observed in the strength of the flexor and external rotator of the right and left hip (Pvalue=0.001 and 0.001, respectively) in the core stability group compared to the control group.

Table 3. Comparison of BMD and strength variables in two groups

Variable	Group	Pre test Mean±SD	Post test Mean±SD	Mean difference	t	Pvalue
Femoral neck BMD (g/cm^2)	Core stability	0.74±0.12	0.82±0.10	-0.08	-4.554	0.001*
	Control	0.68±0.16	0.67±0.16	0.01	2.197	0.045 *
	Pvalue	0.295	0.007 ‡	-	-	-
Right hip flexor strength (% weight)	Core stability	18.74±6.22	40.75±8.95	-22.00	-11.764	0.001*
	Control	14.61±5.51	14.12±5.53	0.49	1.505	0.155
	Pvalue	0.065	0.001 ‡	-	-	-
Right hip external rotation strength (% weight)	Core stability	11.40±3.80	32.36±7.24	-20.96	-13.596	0.001*
	Control	10.82±4.07	10.45±3.94	0.37	0.362	0.723
	Pvalue	0.689	0.001 ‡	-	-	-
Left hip flexor strength (% weight)	Core stability	17.56±5.15	36.88±5.06	-19.31	-22.207	0.001*
	Control	14.22±5.61	14.18±5.26	0.04	0.140	0.890
	Pvalue	0.105	0.001 ‡	-	-	-
Left hip external rotation strength (% weight)	Core stability	11.08±3.19	28.42±5.05	-17.33	-12.485	0.001*
	Control	9.46±3.87	9.36±3.96	0.10	0.110	0.914
	Pvalue	0.258	0.001 ‡	-	-	-

BMD: Bone mineral density. *: Significant differences of intra- group; Pvalue<0.05. ‡ : Significant differences of inter- group; Pvalue<0.05

Discussion

According to the paired samples t-test, the mean BMD of the femur neck in the core stability exercise group increased 0.08 g/cm^2 comparing pre-test and post-test, showing a significant elevation (Pvalue=0.001). In the control group; however, not only was there no increase in the mean BMD of the femur neck but also a significant decline (0.01 g/cm^2) was noticed at the post-test compared to the pre-test (Pvalue=0.045). Besides, according to the results of the independent t-test, the mean BMD of the femur neck at post-test was significantly higher (a mean difference of 0.15 g/cm^2) in the core stability exercise compared to the control group (Pvalue=0.007). These results indicated that four months of core stability exercises could significantly increase the BMD of the femur neck in postmenopausal women.

In accordance with our results, evidence has shown that an effective exercise program can prevent the bone loss of the femur neck or increase bone mass up to 1% per year in women before and after menopause.[19] Likewise, Yung et al. reported a significant increase in the BMD of the proximal femur in postmenopausal women aged more than 55 years old after 24 weeks of core stability exercises, which was similar to our finding. So, according to Yung et al, core stability exercises can increase BMD and prevent osteoporosis in postmenopausal women.[20] The results of a study by Salekzamani et al. showed that postmenopausal women with a history of regular exercise before menopause had a higher hip bone density, which further confirmed the osteogenic effects of mechanical loads.[21] Also, Colletti et al. stated that resistance exercises increase BMD in the areas of the body that can bear the total body weight.[22] Essa et al. also reported a significant improvement in the BMD of the femur neck in the treadmill training compared to the core stability exercise group.[23] This is while our findings demonstrated a significant increase in the BMD of the femur neck after four months of core stability exercises in postmenopausal women. This discrepancy may be related to the duration of the exercise protocols (three months in the study of Essa et al. and four months in the present study). Evidence shows that bone may require four to six months or more for regeneration.[23,24] Therefore, a three-month period that was used by Essa et al. may be inadequate to draw a definite conclusion on the effects of core stability exercises on BMD. Nevertheless, even Essa et al. in their study noticed a slight, but insignificant, increase in the BMD of the femur neck after three months of core stability exercise. So, it can be said that if Essa et al. had used a longer exercise period, they might have achieved different results. It is also noteworthy to mention that Essa et al study, did not include a control group. Moreover, different exercise protocols used in the two studies may be another reason for the different results observed. However, as there are a few national and overseas studies on the effects of core stability exercises on BMD, it is recommended to conduct more research to clarify these effects.

As mentioned, the results of the present study showed that four months of core stability exercises statistically increased the BMD of the femur neck in postmenopausal women (Pvalue<0.05). On the other side, a significant decrease in the BMD of the femur neck was observed in the control group (Pvalue<0.05). These observations indicated that core stability exercises can improve bone mass.

Regular physical activity plays an important role in maintaining bone density, probably via inducing the accumulation of minerals and regeneration of bone.[21] It has been shown that physical activity is associated with higher bone mass and stiffness index[25] and delayed onset of osteoporosis.[26] It seems that mechanical load can affect the osteogenic behavior of bone. The mechanical load can preserve or even increase the bone matrix and decrease apoptosis in osteocytes.[27] Recent reviews on the strategies to prevent osteoporosis in postmenopausal women[10] have shown that exercise can be an effective factor to maintain bone mass or reduce the rate of bone loss during postmenopausal and aging periods.[28] According to a hypothesis, the mechanical pressure exerted on the bone should be at the level to push the balance toward bone formation and regeneration over its resorption (i.e. the minimal effective pressure threshold). The number of training sessions per week and their intensity are among essential factors influencing the response of bones to mechanical or dynamic pressures.[29] Therefore, according to the findings of the present study, it can be said that the load of the core stability exercises has been at the level required to exert minimal effective pressure and therefore increase the BMD of the femur neck.

Another finding of this study showed that four months of core stability exercises significantly increased the muscular strength of lower limbs (flexor and external rotator of the hip) in postmenopausal women (Pvalue<0.05). Other studies have also shown the positive effects of core stability exercises on the strength and power of lower limbs.[18,30] Explaining this finding, it may be said that with the onset of menopause, women's muscular mass and strength decrease with age.[11,12] Although the rate of muscle strength reduction is slow at first, this process rapidly progresses around menopausal age due to a decrease in estrogen and progesterone production. The selective loss of type 2 fibers along with a decrease in physical activity at this age can reduce musculoskeletal loading, which in turn accelerates osteoporosis.[31] Strength is a determining factor of BMD, and evidence shows a significant relationship between the peak torque of the hip flexors and its BMD in postmenopausal women.[32] Indeed, changes in the strength positively predict variations of BMD in postmenopausal women.[14] Consistent with previous notations, an important observation of ours was the significant positive and simultaneous impact of core stability exercises on both the strength of flexors and external rotator of lower limbs and the BMD of the femur neck in postmenopausal women. Evidence shows that the exercises that increase muscle mass and strength also increase bone mass (i.e. BMD) and its rigidity. This effect is valuable as it can either prevent, delay, or reverse bone loss.[26] Furthermore, muscle contraction through stimulating tissue regeneration can increase BMD.[27] Extrinsic forces during exercise enhance BMD via two ways; one is supporting the body mass against gravity, and the other is pulling the bone toward the muscle via its tendon during contraction. These mechanical signals increase the amount of bone marrow mesenchymal stem or multipotent cells that can proliferate into osteoblasts.[4]

Progressive resistance training has been recommended as an effective strategy to increase or preserve bone density in postmenopausal women. These exercises can exert a variety of loads on the bone via direct pulling by muscles or through enhancing the influence of gravity.[10] Increased mechanical stress on the bone during resistance training is a causative factor in bone formation.[27] Our findings also demonstrated the positive effects of core stability exercises (a combination of static contractions and Dynamic resistance movement both stable and unstable) on the BMD of the femur neck in postmenopausal women, which indicated the impact of muscular contractions during these exercises in stimulating bone tissue regeneration. As mentioned, the core acts as a link that facilitates the transfer of torque forces between lower and upper limbs. Therefore, it can also be said that core stability exercises, on one hand, increased the muscular strength of lower limbs, and on the other hand, the increased strength and contraction of these muscles augmented the mechanical load on the femur neck and improved its BMD in postmenopausal women.

The findings of the present study showed that core stability exercises could increase the BMD of the femur neck and the strength of flexor and external rotator of lower limbs in postmenopausal women. Therefore, core stability exercise can be proposed as an effective strategy to influence the osteogenic behavior of bone and reduce the risk of osteoporosis in postmenopausal women.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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