



Original Article

The impact of closed versus open kinetic chain exercises on osteoporotic femur neck and risk of fall in postmenopausal women

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Abstract. [Purpose] This study aimed to investigate how closed and open kinetic chain exercises differed in their impact on bone mineral density (BMD) and fall risk in postmenopausal women with osteoporosis. [Subjects and Methods] The research sample consisted of 40 postmenopausal women with osteoporosis with ages between 51 and 58 years old. They were divided at random into two groups of 20 each, respectively receiving closed and open kinetic chain exercises. These exercises were administered three times per week over a period of four sequential months. Prior to and following the treatment, Dual X-ray Absorptiometry (DEXA) was used to measure the BMD of the femur neck in every participant, while the Biodex Stability System (BSS) was used to estimate how likely each participant was to sustain a fall. [Results] The strongest effect on BMD and fall risk was recorded by the closed kinetic chain exercise. [Conclusion] Osteoporotic postmenopausal women should be prescribed closed kinetic chain exercise to diminish the effects of the disease and minimise their risk of fall.

Key words: Closed kinetic chain exercise, Open kinetic chain exercise, Postmenopausal women

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INTRODUCTION

A systemic bone disease, osteoporosis manifests as gradual reduction in bone mass and degradation of the microarchitecture of bone tissue, which is caused by the fact that bone resorption is more intense than bone formation, making the bone fragile and therefore heightening the risk of fracture¹⁾. Estimates suggest that fractures due to osteoporosis are sustained by 15–30% of men and 30–50% of women over the course of their life. At global level, osteoporosis has come to affect more than 2,000 million individuals, becoming a significant health hazard despite being a silent epidemic²⁾. In the US, in 2010, osteoporotic femur neck or lumbar spine developed in 10.2 million (10.3%) adults of 50 years of age or older, with reduction in bone mass at the site of osteoporosis being recorded in 43.4 million individuals (43.9%). Overall, 53.6 million adults presented both osteoporosis and low bone mass, accounting for about 54% of the American population 50 years of age and older³⁾. In the case of Egypt, various research has revealed that osteopenia and osteoporosis affected postmenopausal women in proportions of 53.9% and 28.4%, respectively^{4, 5)}, while 26% and 21.9% of men were respectively affected by the two diseases⁶⁾. Similarly, in Saudi Arabia, about 23% of women with ages between 50 and 70 years old suffered from osteoporosis⁷⁾. In 2004, 8768 cases of hip fractures due to osteoporosis were recorded⁸⁾.

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In postmenopausal women, the major fall risk factors are balance loss and increased body sway⁹. Fractures sustained due to falls may significantly lower their quality of life, intensifying the financial burden on health services and increasing the likelihood of disease development and death¹⁰. However, as attested by a number of studies, the BMD benefits from physical exercise, the latter thus having a key role in preventing BMD reduction. Strength training was used by several studies to improve BMD^{11–13}, and it is believed that this improvement is due to the bone piezoelectric effect. The occurrence of biochemical signals apparently reflecting an electric field likely as a result of applied overload lends support to this explanation¹⁴.

In older individuals, physical exercise not only diminishes fall risk, but also enhances quality of life¹⁵. For example, in the case of individuals with Alzheimer's, the likelihood of falls can be reduced by enhancing motor function¹⁶. In closed chain exercise (CKC), the body is made to move on a distal segment fixed or stabilised on a surface of support, with movement at joint determining concomitant movement at both distal and proximal joints in a way that can be more or less anticipated¹⁷. In open chain exercise, the distal segment (hand or foot) is not fixed but can move unhindered in space, with movements in neighbouring joints not necessarily occurring concomitantly^{18, 19}. Leg press strength is closely correlated to the BMD of L2–L4 of the lumbar spine and the neck of the femur. Stimulation of bone deposition at these sites can be achieved with exercises that make use of gravitational or ground reaction forces (e.g. stair climbing, walking or jumping with weighted vests)²⁰.

Open-chain exercises involve motions in which the distal segment (hand or foot) is free to move in space, without necessarily causing simultaneous motions at adjacent joints. It performed in non-weight-bearing positions while Closed-chain exercises involve motions in which the body moves on a distal segment that is fixed or stabilized on a support surface and Movement at one joint causes simultaneous motions at distal as well as proximal joints in a relatively predictable manner which stimulate joint and muscle mechanoreceptors, facilitate co-activation of agonists and antagonists (co-contraction), and consequently promote dynamic stability. Also, provide greater proprioceptive and kinesthetic feedback than open-chain training because multiple muscle groups that cross multiple joints are activated during closed-chain exercise, which provide more stress effect on bone that help for stimulation of osteogenesis more sensory receptors in more muscles and intra-articular and extra-articular structures are activated to control motion than during open-chain exercises that improve balance and postural control^{17–19}.

Dual X-ray Absorptiometry (DEXA) is usually applied to diagnose fractures or estimate the risk of fracture at the femur neck and lumbar spine. In fact, hip fracture is most accurately determined by DEXA at the femur neck²¹. Meanwhile, the postural stability assessment and training system known as the Biodex stability system constitutes a multi-axial device that can provide accurate measurements of joint stabilisation capacity under dynamic stress²². Therefore, the present study sought to determine whether postmenopausal women with osteoporosis benefitted more from closed or open kinetic exercises in terms of BMD and fall risk.

SUBJECTS AND METHODS

To assess how closed and open kinetic chain exercises compared in terms of their effect on BMD and fall risk in the case of postmenopausal women with osteoporosis, this study employed a sample of 40 osteoporotic postmenopausal women in the age range 51–58 years old who were treated in Makkah hospitals, Saudi Arabia. All participants completed a consent form before undergoing the study. The study was approved by the research committee of physical therapy department, Faculty of Applied Medical Sciences in Umm Al-Qura University, Makkah, Saudi Arabia. Approved Number: FAMS20160123.

The following inclusion criteria were applied for sample selection: postmenopausal women with osteoporotic femoral neck but without fractures, and a Body Mass Index (BMI) no higher than 30 kg/m². Individuals were not included in the research if they smoked, had a history of hip fractures or had hip operations, presented congenital hip deformities, had taken corticosteroids for a protracted period of time, their BMI exceeded 30 kg/m², or had cancer, kidney disease gastrectomy or any condition that could lead to secondary osteoporosis. The 40 selected participants were randomly divided into two groups. In group I, closed kinetic chain exercises were administered to 20 postmenopausal women with osteoporosis for a duration of 40 minutes thrice weekly over a period of four months while in group II, open kinetic chain exercises were administered to the remaining 20 postmenopausal women with osteoporosis for a duration of 40 minutes thrice weekly over a period of four months. Figure 1 shows the flowchart of the study.

In the case of both groups, femoral neck BMD was qualitatively assessed with the help of Dual X-ray Absorptiometry

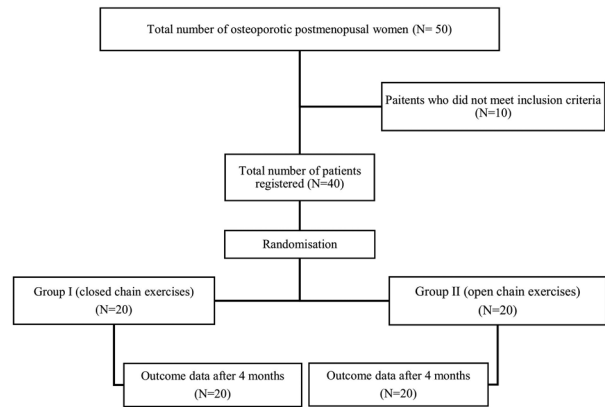


Fig. 1. Flowchart of the study

(DEXA) (Model QDR-1000W, Hologic, Inc., and Waltham, MA, USA). The procedure involves measurement of bone density, which represents the amount of mineral present in a given volume of bone) by subjecting the bone to X-rays with two distinct levels of energy. Diagnosis of osteoporosis is based on this imaging test. Balance and neuromuscular control under dynamic stress are typically measured with the balance device called Biodex Stability System (BSS) (Biodex Medical System Inc., Shirley, NY, USA). This multi-axial device has an unstable balance platform with up to 20° surface tilt in a motion range of 360°. It evaluates postural stability and fall risk based on a scale of twelve levels, with the first and twelfth level respectively being the least and the most stable.

In Group I, twenty osteoporotic postmenopausal women received closed kinetic chain exercises for 40 minutes with 5 minute break between each exercise, which included leg press in horizontal position (15 minutes), bicycling (15 minutes), Stairmaster climbing (10 minutes). If the participants became tired, lost their balance, sweated excessively, were breathless, or experienced chest pain or leg cramps, the exercises were discontinued. In Group II, twenty osteoporotic postmenopausal women received open kinetic chain exercises for 40 minutes with 10 minute break between them, which included straight leg raising, hip shrugging from a half crouch lying position, hip extension from prone lying position, abduction and adduction from side lying position. All participants were required to maintain the position with the leg straight and as high as possible for a couple of seconds. If the participants became tired, lost their balance, sweated excessively, were breathless, or experienced chest pain or leg cramps, the exercises were discontinued.

RESULTS

BMD and risk of fall were analysed and compared between the two groups based on a paired T-test. According to the results obtained, BMD increased significantly ($p < 0.0001$) in group I and insignificantly in group II ($p > 0.05$), while fall risk decreased highly significantly ($p < 0.0001$) in group I and significantly in group II ($p > 0.05$) (Tables 1 and 3). The results of the unpaired t-test showed that, prior to the performance of the exercises, the two groups did not differ significantly in terms of the mean value for BMD and fall risk. However, after performance of the exercises, the two groups differed significantly in terms of the mean value for BMD and fall risk, with the first group exhibiting more notable improvements (Tables 2 and 4).

DISCUSSION

The purpose of the present study was to investigate the effect of closed and open kinetic chain exercises on the BMD and fall risk among postmenopausal women with osteoporosis. The results obtained indicated that, of the two types of exercises, the closed kinetic chain exercises significantly improved both BMD and risk of fall ($p < 0.0001$) in postmenopausal women with osteoporosis. These results were consistent with those of an earlier study, which showed that bone repair in rats subjected to weight-bearing and non-weight-bearing exercises but the bone repair was improved by weight-bearing exercise after two weeks of treatment²³. The results of this study were also similar to Vincent et al. findings, which indicated that higher intensities related to maximum load were usually associated with higher stimuli, stimulating and having a more immediate effect on BMD compared to lower training intensities²⁴. In addition, DeSure et al. found that strength, balance, proprioception and gait were all improved by regular physical exercise²⁵. Moreover, exercise programs focused on the promotion of physical fitness could contribute to minimise the risk of falls among institutional care patients²⁶.

Table 1. Pre- and post-treatment mean values of BMD for group I and group II

		Pre-treatment	Post-treatment	MD	Improvement %
Group I	Mean	-2.9	-2.4	-0.5*	16
	SD	-0.2	-0.5		
Group II	Mean	-2.9	-2.8	-0.1	4.7
	SD	-0.3	-0.3		

SD: standard deviation; MD: mean difference

* $p < 0.05$

Table 2. Pre- and post-treatment mean values of BMD between group I and group II

		Group I	Group II	MD
Pre-treatment	Mean	-2.9	-2.9	-0.1
	SD	-0.2	-0.3	
Post-treatment	Mean	-2.4	-2.8	-0.4*
	SD	-0.5	-0.3	

SD: standard deviation; MD: mean difference

* $p < 0.05$

Table 3. Pre- and post-treatment mean values of fall risk in group I and group II

		Pre-treatment	Post-treatment	MD	Improvement %
Group I	Mean	4.1	3.1	1.1*	25.4
	SD	0.3	0.2		
Group II	Mean	4.2	3.9	0.2*	5
	SD	0.3	0.2		

SD: standard deviation; MD: mean difference

*p<0.05

Table 4. Pre- and post-treatment mean values of fall risk between group I and group II

		Group I	Group II	MD
Pre-treatment	Mean	4.1	4.2	0.1
	SD	0.3	0.3	
Post-treatment	Mean	3.1	3.9	0.9*
	SD	0.2	0.2	

SD: standard deviation; MD: mean difference

*p<0.05

The present study was also in agreement with previous study that reported that functional balance, muscle strength, mobility, disability and falling risk were all improved by exercise programs of moderate intensity specifically designed for fall prevention^{27, 28}). The study also concurred with Menkes et al. results who found that bone compression, tension, torsion or shear was a causative factor of bone overload. The differences in the bone's electrical power produced by such mechanical forces act as an electrical field that promotes cellular activity, causing minerals to be deposited in the areas under stress¹⁴). Another study contributed to reinforce existing evidence that strength training is among the physical activities that promote bone formation²⁴). Furthermore, Liu et al. has also indicated that exercises engaging the body weight or generating significant muscular strength as overload have an osteogenic effect. For example, individuals performing sports that involve such exercises were found to exhibit a higher BMD compared to non-athletes²⁹). The study results were in line with earlier evidence that individuals of all ages can derive bone mass benefits from physical exercise, with bone strength being particularly enhanced by short, repetitive and multidirectional mechanical loading exercises^{30, 31}).

The results obtained in the present study provided support for the fact that the BMD and fall risk of postmenopausal women with osteoporosis could both be improved by closed kinetic chain exercises. Therefore, it is worth integrating these exercises with other strategies for the treatment of osteoporosis.

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