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Effects of osteoanabolic exercises on bone mineral density of osteoporotic females: A randomized controlled trial

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ABSTRACT

Objectives: With the increase in the life expectancy of older adults, the scoring diagnosis of osteoporosis has been highly reported hence rising the incidence of fragility fractures due to decrease in bone mineral density (BMD), thereby significantly impacting the quality of life and health status of elderly population. The aim of this study is to identify the impact of different exercise regimes in improving the BMD among osteoporotic females.

Methodology: A trial was conducted on 93 diagnosed postmenopausal osteoporotic females aged 50–75 years screened on the basis of physical activity readiness-questionnaire and YOU form randomly divided equally into three groups', that is, aerobic, anaerobic, and osteoanabolic exercises using an envelope method. The intervention was given on the basis of American College of Sports Medicine (ACSM), frequency, intensity, time, and type protocol for the period of 12 weeks. The pre- and post-BMD was determined to find out the improvements on the *t*-value of the participants. The outcome measure was calculated using a peripheral dual X-ray absorptiometry scan (bone densitometer).

Results: At 95% of confidence interval, the pre- and post-median difference observed within the osteoanabolic group was 0.4 followed by 0.3 and 0.1 in the aerobic and anaerobic groups, respectively. The level of significance was determined by applying the Friedman test revealing a statistically significant difference $P < 0.001$ between the groups. Further, *post hoc* analysis shows that osteoanabolic exercises were more significant in comparison with aerobic and anaerobic exercises.

Conclusion: Structured physical exercises based on ACSM protocol show improvement among the osteoporotic females; however, the impact of osteoanabolic exercises significantly increased the BMD, thus reducing the *t*-value. However, larger scale studies in different clinical settings are recommended for more accurate results.

Keywords: Bone mineral density, densitometry, exercises, osteoporosis, postmenopause

Introduction

Osteoporosis is a global challenge and it is estimated that around 200 million people are osteoporotic,[1] affecting one of every three women who are at a risk of having osteoporotic fracture that limits the activities of daily living and is indeed one of the causes of physical inactivity (International Osteoporotic Foundation, 2015).[2] According to osteoporotic facts and statistical analysis provided by the Foundation of Osteoporosis Canada in 2015, osteoporotic fractures are more common than heart attack, stroke, and breast cancer creating an estimated economic burden of around $2.3 billion Canadian dollars annually.[3] According to the data provided by Wade *et al*. on 10 years of probabilities of osteoporotic fractures, elderly population who have sustained any previous fracture due to osteoporosis are at 50% of increased risk to future fractures. Moreover, it is also estimated that a previous wrist fracture may increase a risk for having hip and vertebral fracture with an estimated relative risk of around 1.9 and 4.4, respectively.[4] Osteoporosis causes >8.9 million of the fractures worldwide which makes it approximately 1000 cases per hour.[5] According to another study conducted on the population of China, it is estimated that the annual cases of osteoporotic fractures as reported during the year 2011 are 40% greater than the sum of cases reported for the breast cancer, endometrial cancer, and ovarian cancer among women.[6]

Similar findings have also been reported for male population where the incidence of osteoporotic fractures reported during the same year is 13% greater than the cases reported for prostate cancer.[7] The situation in the neighboring country India is also similar where it is estimated that around 50 million people are either osteoporotic or have low bone mass.[8] Besides Asian-Pacific region, the high rate of incidence of osteoporotic fractures has also been reported in the United States, Europe, and the United Kingdom.[9] According to the study conducted by Clifford *et al*., in 2017, the annual incidence of osteoporotic fractures as reported in the United States is approximately 0.3 million, for Europe, the number of incidents reported is 1.7 million, and for the United Kingdoms, the incidence is reported as 400/100,000 women.[10] In Pakistan, the situation is even alarming where osteopenia is reported in 64% of women population of Karachi <30 years and 55% of women <45 years of age,[11] whereas 24.7% of the cases in KPK are reported as osteoporosis.[12] Out of the copious risk factors of osteoporosis, general factors such as aging, gender, body composition, dietary intake, genes, and physical inactivity are classified as a primary, whereas medication and disease induced are classified as secondary risk factors.[13] According to the World Health Organization, the diagnosis of osteoporosis is mainly done on the basis of bone mineral density (BMD) calculated using a dual X-ray absorptiometry (DXA) scan where *t*-score of ≥−1.0 is considered as normal, value ≤−1.0 and ≥−2.5 osteopenia, ≤−2.5 is osteoporosis, and ≤2.5 with fragility fracture is diagnosed as severe osteoporosis.[14]

According to the study conducted in 2015, basic lifestyle modifications such as regular physical activities, plummeting risk of fall, nutritional, dietary counseling plus modification, early bone screening, and bone loss prevention are turned out to be an essential management strategy for osteoporosis.[15] The estimated role of exercises is found to be significant, it not only improves bone mineral concentration but also indeed reduces the risk of fall, improves balance and agility, and increases muscle strength and muscle mass. Physiologically, the response of exercises is greatly dependent on the intensity, duration, type, and frequency of the exercise. Studies have provided evidence that aerobic and resistance exercises modestly increase the BMD through mechanical loading induced by physical activity which produces strain within the bone, providing impetus to the osteoblastic activities in the quiescent state resulting in bone remodeling and resorption. In a study conducted in 2017 on postmenopausal women, physical exercises meant to prevent and fight against the age-related bone loss;[16] meanwhile, in another study conducted on the effect of short-term step, aerobic exercises among 48 postmenopausal women with low bone mass showed a significant improvement on BMD.[17] The evidence provided by Zhao *et al*. after pooling the effect of 24 randomized controlled trials, suggested that the combined resistance training proved to be effective in improving BMD due to its high level of mechanical strain which generates the beneficial effects on the bone health of postmenopausal women.[18] Although the number of literature has provided evidence on the impact of exercise on BMD in postmenopausal women, the effects of osteoanabolic (combination of aerobic + anaerobic) exercises have not been discussed in detail, thereby create an opportunity for this research paper. Hence, the present study is aimed to determine and compare the effects of three different exercises regimes protocol, that is, aerobic, anaerobic, and osteoanabolic exercises on BMD of postmenopausal osteoporotic women.

Methodology

A randomized controlled trial was conducted in which 93 diagnosed osteoporotic females were divided equally into three groups using an envelope method technique. The study was carried out in a tertiary care hospital of Karachi and the intervention was designed on the basis of American College of Sports Medicine (ACSM); frequency, intensity, time, and type protocol given for the period of 12 weeks. The pre- and post-BMD of the participants were determined based on *t*-score; the descriptions of the management strategies used in this study based on the guidelines of ACSM are given as follows:

Group A (aerobic exercises):
- Frequency: 6 days/week
- Intensity: For aerobic exercises, 55–75% of maximum heart rate for 6 days and
- Time: 30–60 min
- Type: Treadmill, cycling, and resistance exercises.

Group B (anaerobic exercises):
- Frequency: 3 days/week
- Intensity: Repetition to failure (1 RM formula)
- Time: Time required in performing 10–15 repetition of 10 major muscles group with low-intensity weight.
- Type: Dumbbell and weight lifting (resistant exercises).

Group C (osteoanabolic exercises):
- Frequency: 6 days/week
- Intensity: For aerobic exercises, 55–75% of maximum heart rate for 3 days and repetition to failure (1 RM formula) with moderate intensity 3 days/week
- Time: 30–60 min
- Type: Treadmill, cycling, and resistance exercises

It was also taken into account that the training session was prematurely been terminated on the happening of one of the following events:
- Modified Borg dyspnea scale rating of perceived exertion at level 8 or above
- Complain of chest pain
- Decrease in oxygen saturation
- Able to speak but not sing comfortably during the exercises.

The outcome measure was calculated using a peripheral DXA scan (bone densitometer); the measurements were taken before the start of the session, that is, on the 1st day of week 1 and were compared with the measurements taken on the past day of week 12.

Inclusion criteria

- Age: 50–75 years[19]
- Diagnosed postmenopausal osteoporotic females
- Successful screening on the basis of physical activity readiness-questionnaire form[20] is a simple self-screening tool that can be filled by either patients or physical therapist who is planning to start an exercise program.

Exclusion criteria[21,22]

- Red flags that limit recruitment of participants in exercise program, for example, vertebral fracture, malignancy, etc.
- Cardiac disease
- Mental disorders
- Neurological disorders associated with high risk of fall, for example, stroke, parkinsonism, dementia, Alzheimer, etc.

Ethical consideration

Ethical considerations were made according to guidelines provided under the Belmont report for human subjects. The data provided by the participants were kept confidential; consent was taken before the recruitment and participants were given opportunity to ask any question before, during, and after the completion of the study.

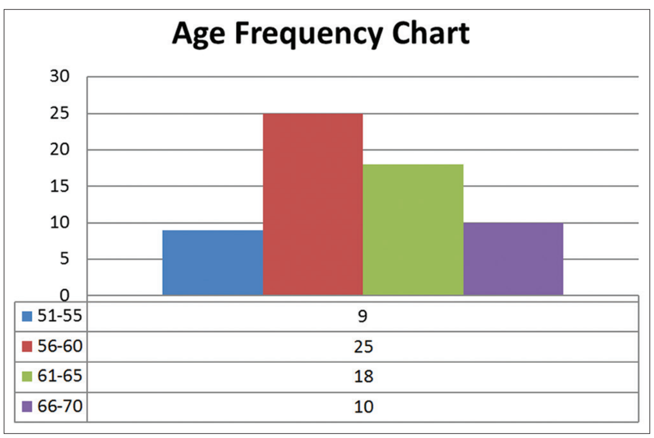

Figure 1: Age graph chart

Results

A total of 93 participants were included in 12 weeks of intervention program divided into three subgroups, that is, aerobic ($n = 31$), anaerobic ($n = 31$), and osteoanabolic ($n = 31$). During the course of the study, no injury or harm was witnessed to the participants.

The age frequency graph of the participants recruited in the study is given in Figure 1.

The age frequency graph showed that the maximum number of the participants in both the groups was found in between the age bracket of 56 and 60 years ($n = 25$) followed by 61–65 years of age ($n = 18$), 66–70 years ($n = 10$), and 51–55 ($n = 9$). Significant effects of exercises on BMD were observed in all three groups, that is, aerobic, anaerobic, and osteoanabolic. Wilcoxon test with 95% of confidence interval (CI) was applied that reveals a statistically significant improvement $P < 0.001$ in the BMD of the postmenopausal women included in the study (Table 1).

At 95% of CI, the median difference (pre-post) as observed in the osteoanabolic group was greater than aerobic and anaerobic groups, respectively (osteoanabolic > aerobic > anaerobic). To determine the level of significance, the Friedman test was applied which revealed a statistically significant $P < 0.00001$ results between the groups (Table 2).

Further, *post hoc* test was run which suggested that the effects of osteoanabolic exercises were more significant in comparison to aerobic and anaerobic exercises. The results also revealed that the difference between aerobic groups was more significant than anaerobic group (Table 3).

Graphical representation of the differences in the post *t*-value between the groups is illustrated in Figure 2.

Discussion

The result of the study on the BMD of the participants depicts that exercise had a positive impact on *t*-value of the participants. The aerobic exercises protocol of 6 days a week for a period of 12 consecutive weeks significantly reduces

Table 1: The pre-post analysis on *t*-values of BMD within the group

Statistical Description	Aerobic		Anaerobic		Osteoanabolic	
	Pre	Post	Pre	Post	Pre	Post
Sample size	31	31	31	31	31	31
Median with SD	2.6±0.2	2.3±0.2	2.6±0.16	2.5±1.25	2.6±0.2	2.2±0.2
95% CI for the median	−2.7–−2.5	−2.3–−2.1	−2.7–−2.5	−2.5–−2.5	−2.6–−2.5	−2.3–−2
Median difference	0.3		0.1		0.4	
P value	0.000001		0.000065		0.000001	

Table 2: Comparison among the group

Group	*n*	Median	F	DF 1	DF 2	*P* value
Post-aerobic	31	−2.3	16.35	2	60	<0.00001
Post-anaerobic	31	−2.5				
Post-osteoanabolic	31	−2.2				

Table 3: *Post hoc* analysis between the groups

Group	Sig. (two-tailed)
BMD anaerobic - BMD aerobic	0.002
BMD osteoanabolic - BMD aerobic	0.313
BMD aerobic - BMD anaerobic	0.002
BMD osteoanabolic - BMD anaerobic	0.001
BMD aerobic - BMD osteoanabolic	0.313
BMD anaerobic - BMD osteoanabolic	0.001

BMD: Bone mineral density

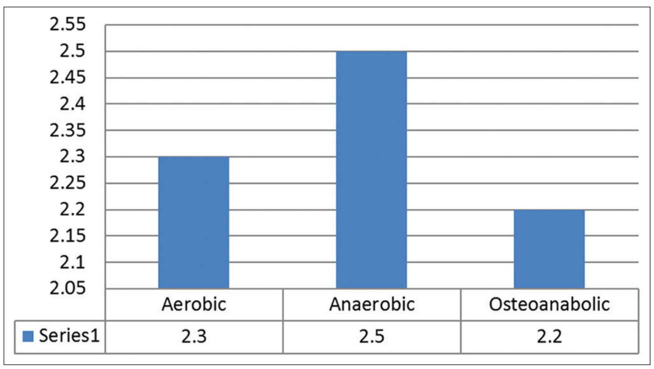

Figure 2: Difference in bone mineral density between groups

t-value of the participants. On the other hand, osteoanabolic exercises were also found to be significantly effective. The result was according to the study conducted by Lloyd *et al*., in 2014,[23] and Stanghelle *et al*., in 2018,[24] where it was concluded that exercise training results in an increase BMD as it causes an increased stress on bone cell due to the extra forces exerted by the muscle fibers which results in the inducement of the process of bone remodeling. It was further analyzed from various different researches that an increase in the muscle strength with the involvement of one of the basic principles of training, that is, the principle of overload (which is the progressive increase in the resistance, duration, and frequency of exercises to improve the baseline threshold) and the process of bone remodeling increases to multifold (a basic physiological response of exercise stressor on bone) that not only prohibits bone mineral loss but also indeed persuades the process of osteoblasts and osteoclasts.[25,26] However, Abrahin *et al*., in 2016, concluded that the impacts of aerobic exercises, particularly cycling and swimming, did not had any positive outcome on the BMD of the participants.[27] Similar results were also been observed by Carbuhn *et al*., in 2010, and Miller *et al*., in 2018, in which it was concluded that swimming which considered as one of the non-impact physical aerobic activities did not had any significant changes in the BMD; moreover, even an increased in intensity during training of around 60%–90% of MHR had no impact on any change in the BMD.[28,29] Silva *et al*., in 2011, concluded that of all the different aerobic physical activities including swimming, soccer, and tennis; swimmers had the lowest femoral BMD in comparison to other sports activities, which further endorsed that only impact exercises that place weight-bearing forces on the skeletal system of human body could stimulate the process of local osteogenesis.[30] The studies had also revealed that exercises involved in the use of resistance training; creates strain on muscles subsequently induces the process of bone remodeling and reabsorption. Moreover these exercises intensify the osteoblast and osteoclast activities and improve BMD.[31] Moreover, according to the study conducted by Helge *et al*., in 2014, the estimated increase in the BMD as observed after 12 months of high impact recreational physical activity was 5.4% from the baseline, more than what had been observed by the researchers during different physical activities.[32] Interesting findings had been observed by Ernest *et al*., in 2018, in which they divided the participants into three group according to the impact of exercises that are high impact (runners), low impact (swimmers), and control group which they described as a sedentary group and they found that low impact group exercises had BMD even lesser than the BMD of the control group with a difference of around −9.8%, whereas the subjects in the high impact group had an estimated increased in the BMD of around 8%, 10%, and 6.3% from the baseline in legs, trunk, and total body, respectively.[33] The present study had also revealed a similar type of findings where both impact exercise, that is, aerobic and osteoanabolic showed a similar level of improvement after the completion of the 12 weeks of exercise session. Further, it was also observed that the impact of osteoanabolic interventional strategies was more in terms of median value as it involved the use of both aerobic and anaerobic exercises session. However, a few limitations were identified in this study such as the BMD was determined through peripheral DXA scan due to budgetary constraint, whereas the gold standard suggests BMD to be determined at lumbosacral. Moreover, no follow-up was conducted to find out the residual effects after 6 months or a year, and finally, most of the patients were in the age bracket of 56–60 years which may affect the generalizability of the result among patient with older age, that is, >65 years.

Conclusion

The study concluded that the impact of osteoanabolic exercises showed a significant improvement in reducing *t*-score (calculated using a peripheral densitometer) of the participants in comparison to aerobic and anaerobic exercise regimes.

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