Spor Hekimliği Dergisi, 58(2):88-93; 2023
Turkish Journal of Sports Medicine
Turk J Sports Med. DOI: 10.47447/tjsm.0744

Research Article / Araştırma Makalesi

Effect of short-term Pilates exercises on bone mineral density and physical performance in older women

Kısa süreli Pilates egzersizlerinin yaşlı kadınlarda kemik mineral yoğunluğu ve fiziksel performans üzerine etkisi

Kadriye Sevilay Bayram[1], Gülşah Şahin[2], Coşkun Zateri[3], Ali Coşkun[4]

[1]Institute of Postgraduate Studies, Çanakkale Onsekiz Mart University, Çanakkale, Türkiye [2]Faculty of Sports Sciences, Çanakkale Onsekiz Mart University, Çanakkale, Türkiye [3]Faculty of Medicine, Çanakkale Onsekiz Mart University, Çanakkale, Türkiye, [4]Bayramiç Vocational School, Çanakkale Onsekiz Mart University, Çanakkale, Türkiye

ABSTRACT

Objective: Although high-stress exercises on the bone have been emphasized in previous research on BMD, high intensity exercises may increase the risk of injury in inexperienced older women. Also, these exercises are not recommended due to risk of injury or other problems in fragile older adults. Due to the fact that it is one of the most preferred methods by postmenopausal women, our study focused on the effects of the Pilates method on bone mineral density. The aim of this study was to determine the effect of short-term Pilates exercise on bone mineral density and physical performance in older women.

Methods: Twenty-three older women were voluntarily involved in this research (Pilates group, n=13, and control group, n=10). The Pilates group participated in Pilates exercise for 12 weeks, two days per week. Bone mineral density and physical performance were evaluated. The prospective case-control, pre- and post-test study was conducted at the Çanakkale University Hospital. All measurements were repeated following three-months. The Mann-Whitney U test was used to compare groups, and the Wilcoxon test was used to assess differences between pre- and post-exercise measurements for each group.

Results: After three-months, there was an increase in physical performance scores in the Pilates group (p=0.013). Although there was an improvement in bone mineral density of older women in the Pilates group, it was not statistically significant (p>0.05).

Conclusion: It is possible to say that "short-term Pilates exercise does not produce a resistance training effect on bone mineral density of postmenopausal women". However, Pilates is effective for improving physical performance in older women.

Keywords: *Pilates, bone mineral density, physical performance, DEXA, aging*

ÖZ

Amaç: BMD ile ilgili önceki araştırmalarda kemik üzerinde yüksek stresli egzersizlerin etkisi vurgulanmış olsa da, yüksek yoğunluklu egzersizler deneyimsiz yaşlı kadınlarda yaralanma riskini arttırabilir. Ayrıca bu yöntem kırılgan yaşlı yetişkinlerde farklı sorunlar nedeniyle de önerilmemektedir. Menopoz sonrası dönemdeki kadınların en çok yeğlediği yöntemlerden biri olması nedeniyle bu çalışmada Pilates yönteminin kemik mineral yoğunluğu üzerindeki etkileri üzerinde duruldu. Bu çalışmanın amacı, yaşlı kadınlarda kısa süreli Pilates egzersizinin kemik mineral yoğunluğu ve fiziksel performans üzerine olası olumlu etkilerini belirlemektir.

Gereç ve Yöntem: Çalışmaya 23 yaşlı kadın katıldı (Pilates grubu, n=13 ve kontrol grubu, n=10). Pilates grubu, 12 hafta boyunca haftada iki gün Pilates egzersizlerine katıldı. Kemik mineral yoğunluğu ve fiziksel performans değerlendirildi. Prospektif olgu kontrollü ön test ve son test çalışması, Çanakkale Üniversitesi Hastanesinde gerçekleştirildi. Tüm ölçümler üç ay sonra tekrarlandı. Gruplar arası karşılaştırmalarda Mann-Whitney U testi, her grup için egzersiz öncesi ve sonrası ölçümler arasındaki farkları belirlemede Wilcoxon testi kullanıldı.

Bulgular: Üç ay sonra Pilates grubunda fiziksel performans skorunda artış oldu (p=0.013). Pilates grubundaki yaşlı kadınlarda kemik mineral yoğunluğunda artış vardı ama istatistiksel olarak anlamlı değildi (p>0.05).

Sonuç: Kısa süreli Pilates egzersizlerinin postmenopozal kadınların kemik mineral yoğunluğu üzerinde bir direnç antrenmanı etkisi yaratmadığını söylemek mümkündür. Bununla birlikte, Pilates yaşlı kadınlarda fiziksel performansı arttırmak için etkilidir.

Anahtar Sözcükler: *Pilates, kemik mineral yoğunluğu, fiziksel performans, DEXA, yaşlanma*

INTRODUCTION

Bone mineral density (BMD) is one of the important parameters for daily living activities and quality of life in older women. Deteriorations in BMD may cause an increased risk of falling and reduced parameters of physical performance (1,2). Hip, vertebral and non-vertebral fractures include severe complications like chronic pain, disability, low quality of life and early mortality (3). Moreover, the estrogenic response to mechanical loading decreases with age (4). During

Received / Geliş: 04.12.2022 · **Accepted / Kabul:** 16.02.2023 · **Published / Yayın Tarihi:** 23.05.2023

Correspondence / Yazışma: Gülşah Şahin · Canakkale Onsekiz Mart Üniversitesi, Spor Bilimleri Fakültesi, Canakkale, Türkiye · nazgulsah@hotmail.com

Cite this article as: Bayram KS, Sahin G, Zateri C, Coskun A. Effect of short-term Pilates exercises on bone mineral density and physical performance in older women. *Turk J Sports Med.* 2023 58(2):88-93; https://doi.org/10.47447/tjsm.0744

the postmenopausal period, decreased estrogen levels may cause some harmful changes for health (5).

Regular exercise is considered as an important strategy to prevent and treat age-linked bone weakness (6). Previous studies have shown that it is possible to improve physical fitness, BMD and body composition, to improve balance and to reduce risk of falling via physical training programs (7-12). Resistance exercise is considered as a low cost and safe treatment strategy for the protection of musculoskeletal health and fracture prevention; therefore, numerous studies have focused on the effects of exercise on BMD in post-menopausal women (13). It is known that high-intensity resistance exercises are more effective in maintaining or increasing BMD, especially in the postmenopausal period (14).Despite the advantages of resistance exercise on BMD, strength or resistance exercise may not always be preferred by older adults due to its difficulty. In addition, fear of injury and pain caused by strength training has been reported as a barrier involving in exercise (15).

Contrary to resistance exercise; Pilates, including balance, flexibility, breathing, posture and resistance exercises, is becoming popular in the rehabilitation process of the older adults (16,17). However, there is no clear data on whether Pilates exercise has similar effects on BMD as a resistance exercise in older women. One study determined the effect of the Pilates method on BMD in older women with osteoporosis (18). It is also known that Pilates is motivating and has lower rates of withdrawal and injury (19). This might be crucial especially for older individuals (20). Although high-stress exercise effects on the bone have been emphasized in previous research on BMD, high intensity exercises may increase the risk of injury in inexperienced older women. Also, these exercises are not recommended due to the other problems in fragile older adults. Due to the fact that it is one of the most preferred methods by postmenopausal women (21), our study focused on the possibly positive effects of the Pilates method on bone mineral density.

In our study, to confirm this hypothesis, BMD of postmenopausal older women was measured with radiographic techniques (DEXA) before exercise and after three months. The primary aim of this study was to determine the possibly positive effects of short-term Pilates exercise on BMD of healthy older women. The second aim was to investigate its again possibly favorable effects on BMI, fat %, FFM, waist and hip circumference, and physical performance.

MATERIAL and METHODS

Participants and procedure

The prospective, case-control, randomized controlled and single-blind study was conducted at the Çanakkale Onsekiz Mart University Health, Research and Practice Hospital in the March 2019- January 2020 period. The first assessment and evaluation was conducted prior to the Pilates program. The second evaluation was performed following three months. The Pilates group participated in 50 min Pilates exercises throughout the 12 weeks.

Participants were recruited from the activity center for older adults with an announcement. Thirty women were randomly separated into Pilates (n=15) and Control (n=15) groups. Participants were evaluated at the University Hospital-Physical Medicine and Rehabilitation department by a physician. Following clinical evaluation, participants that were: 1) volunteers, 2) of community-dwelling status, 3) between 65-80 years of age, 4) not under any therapy and exercise intervention, and 5) without any physical or mental illness were included in the study. Exclusion criteria included: 1) any health problems, 2) severe cardiac disease, 3) uncontrolled hypertension, 4) unregulated diabetes mellitus, 5) severe shortness of breath, 6) neuromuscular diseases, 7) inflammatory rheumatic diseases, 8) physical and mental disability, 9) to be unable to walk without support, 10) using drugs affecting the central nervous system, 11) receiving osteoporosis treatment in the last year, 12) receiving calcium and vitamin D supplements, and 13) to have participated in any training program in the last six months.

Participants were informed regarding the exercises and tests. Researchers explained about possible muscular soreness risks due to the Pilates exercise. During the process, some participants withdrew from the study due to moving to another city, thinking they could not continue regularly, experiencing health problems not linked to exercise, not wanting to perform measurements again, and unknown reasons. Therefore, the research was resumed with 23 older women. The flow diagram of the research is presented below (Figure 1). All participants were asked to sign an informed consent form. The study was approved by the Çanakkale Onsekiz Mart University Medical Faculty Clinical Research Ethics Committee (Date: 13.03.2019, Number: 18920478-050.01.04-E.1900042414, Decision no: 2019-06). The research was supported by the Çanakkale Onsekiz Mart University Scientific Research Projects Commission (Project ID: 2925). All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and complying with the 1964 Helsinki Declarati–

on and its later amendments or comparable ethical standards.

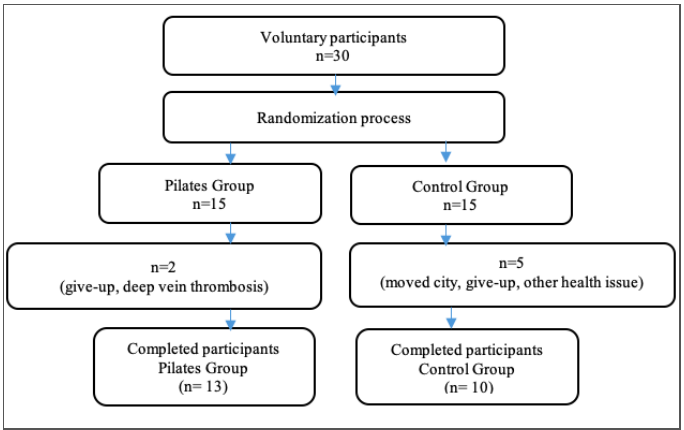

Figure 1. Flow diagram of the study process

Outcome measures

Bone mineral density measurement: Bone mineral density was measured with dual energy x-ray absorptiometry (DEXA) (Lunar, General Electric) at the proximal femur level on the nondominant side using standard protocols. DEXA measurements yielded BMD, T and Z scores for L1-L4, total hip and femur neck. All scans were performed by the same clinical technician using standard procedures. Women laid flat on the scanning bed, and were positioned in the center aligned with the long axis of the scanner, with arms and legs evenly separated to allow for accurate analysis. The DEXA scanner was calibrated within 24 h prior to every scan.

Physical performance evaluation: The short physical performance battery (SPPB) was used to evaluate physical performance. The assessment was recorded side-by-side with tandem and semi-tandem stances, 4-m walk test, five times sit-stand test, and the duration to complete these tests. Points were given as follows: two-foot side-by-side stance <10s 0 points, >10s 1 point, semi-tandem stance <10s 0 points, >10s 1 point, and tandem stance duration <3s 0 points, 3-9.99s 1 point and >10s 2 points. For the 4-meter walking test, inability to walk 0 points, >8.70s 1 point, 6.21-8.70s 2 points, 4.82-6.20s 3 points and <4.82s 4 points. For the five times sit-stand test, inability to perform the movement 0 points and according to the duration ≤60 sec, points were given between 1 to 4 (22).

Body composition evaluation: Body height was measured without shoes with a stadiometer (SECA, Germany). Body weight was measured without shoes and wearing light clothes only, using a body composition analyzer. Waist and hip circumferences were measured by a non-elastic tape. Body mass index, fat ratio, fat-free mass (FFM) were assessed by bioelectrical impedance analysis (BIA) with a body composition analyzer (TANITA, TBF-310 GS, Tokyo, Japan). Participants were asked to avoid any exercise or physical activity, caffeine consumption or eating for three hours prior to the analyzes.

Pilates mat exercise intervention: The Pilates group performed 50 min of Pilates exercises for 12 weeks (Table 1). Each exercise class was performed two days per week. The elastic band was used for resistance in Pilates exercises. Prior each class, general health status of participants was evaluated through heart rates and blood pressures. During the first four weeks only mat exercises were used, while the last eight weeks elastic band work was added. Participants were permitted to leave the exercise class after their blood pressure and heart rate levels reached resting levels. There were no cases regarding any health problem linked to exercise. The control group were asked to continue their daily activity throughout the study.

Table 1. Pilates mat exercise protocole

Phases	Duration	Content	Frequency
Warm-up	»5 min	Breathing, and movements to increase shoulder and hip joint movement angles	Twice/wk
Mat Pilates	40 min	*Mat Pilates phase (four weeks)* Abdominal, back, spine, arm, leg and hip movements like the hundred, one leg circle, side kick, swan, swimming, saw, bridge, spine stretch, lower back, spine twist, side-leg stretch exercise. *Mat Pilates and elastic band phase (eight weeks)* Similar exercises as above with an elastic band.	
Cool-down	»5 min	Stretching and heart rate check	

Statistical Analysis

Descriptive data were presented as mean, SD, confidence interval and range. The verification of data normality was performed through the Shapiro-Wilk test; and the Levene test was used to evaluate the equality of variances. To verify differences between the groups with regard to baseline physical characteristics (age, weight, height and BMI) and BMD, body composition and physical function scores at the pre-exercise, the Mann-Whitney U test was used. The Wilcoxon test was used to compare within group differences. The confidence interval permitted in all tests was 95% ($p \leq 0.05$). Data were analyzed with the SPSS 26.0 (SPSS Corp., Chicago, IL, USA) program.

RESULTS

Table 2 presents the physical characteristics and ages of older women in the Pilates and control groups at the baseline. There was no significant difference for the parameters between the groups at the baseline ($p > 0.05$).

Table 2. Baseline physical data for the study groups

Group	Pilates group(n=13)		Control group (n=10)			
Parameter	**Mean**	**Range**	**Mean**	**Range**	**z**	**p**
Age (year)	70.2±3.8	65.0-77.0	71.5±4.5	68.0-80.0	-0.878	0.380
Height(cm)	152.8±5.1	145.0-161.0	140.8±9.2	157.0-163.0	-1.119	0.263
Body weight (kg)	71.1±10.2	54.5-89.4	72.2±10.4	54.9-88.3	-0.031	0.975
Figures as mean ± SD						

At the baseline, there was no significant difference between the groups for BMI, fat ratio, FFM, waist circumference, hip circumference, balance, 4 m walk test score, sit to stand test score, L1-L4 T score, L1-L4 Z score, L1-L4 BMD, femur neck T score, femur neck Z score, femur neck BMD, total T score, total Z score, and total BMD (p>0.05) (Table 3).

Table 3. Baseline test results for the study groups

	Pilates group (n=13)		Control group(n=10)		
Baseline test	**Mean (95% CI)**	**Range**	**Mean(95% CI)**	**Range**	**p**
BMI ($kg.m^{-2}$)	30.6 (27.4-33.8)	21.3-36.8	29.6 (26.7-32.5)	24.5-37.7	0.975
Fat ratio (%)	39.1 (35.9-42.7)	24.4-46.3	37.2 (31.7-42.6)	18.4-45.7	0.385
FFM (kg)	42.7 (40.9-44.6)	37.5-48.5	44.7 (42.8-46.6)	40.1-47.9	0.620
WC (cm)	87.0 (81.4-92.6)	69.0-98.0	93.6 (88.8-98.4)	85.0-102.0	0.128
HC (cm)	108.4 (103.0-113.7)	92.0-127.0	109.5 (102.6-116.4)	95.0-124.0	0.136
		SPPB (scores)			
Balance	3.54 (3.22-3.85)	3.00-4.00	3.80 (3.49-4.10)	3.00-4.00	0.202
4 m walk	3.77 (3.50-4.03)	3.00-4.00	3.10 (2.47-3.72)	2.00-4.00	0.077
Sit-to-stand	3.76 (3.50-4.03)	3.00-4.00	3.00 (2.10-3.89)	1.00-6.00	0.106
Total score	11.1 (10.6-11.5)	10.0-12.0	9.90 (8.49-11.3)	6.00-12.0	0.153
		BMD ($g.cm^{-2}$)			
L1-L4 T score	-0.63 (-1.38-0.12)	-2.20-1.60	-1.05 (-1.87 to -0.22)	-2.90 to -0.40	0.709
L1-L4 Z score	0.71 (0.06-1.34)	-0.90-2.80	0.30 (-0.40-1.00)	-1.50-2.00	0.351
L1-L4 BMD	1.07 (0.97-1.16)	0.87-1.34	1.02 (0.91-1.12)	0.78-1.19	0.804
Femur neck T sco.	-1.11 (-1.49 to -0.71)	-2.20-0.10	-1.35 (-1.93 to -0.76)	-2.40-0.00	0.336
Femur neck Z sco.	0.39 (0.10-0.67)	-0.30-1.20	0.19 (-0.42-0.80)	-0.90-2.10	0.367
Femur neck BMD	0.83 (0.78-0.87)	0.70-0.95	0.80 (0.73-0.87)	0.68-1.02	0.352
Total T score	-0.82 (-1.29-0.34)	-2.70-0.00	-1.11 (-1.72 to -0.49)	-2.10-0.80	0.172
Total Z score	0.30 (-0.06-0.66)	-1.00-1.50	0.00 (-0.65-0.65)	-1.40-2.00	0.113
Total BMD	0.90 (0.84-0.95)	0.68-1.00	0.86 (0.79-0.93)	0.75-1.23	0.172

Figures as means (95% CI). CI: confidence interval; BMI: body mass index, FFM: fat free mass, HC: hip circumference, WC: waist circumference, BMD: bone mineral density, SPPB: short physical performance battery

Table 4 displays the comparison for all tests between the Pilates group (PG) and the control group (CG). The PG group demonstrated significant improvement (p<0.05) for the waist circumference, and 4m walk, sit to stand and total physical performances. However, there was no significant change in BMD in the Pilates group. Pilates did not significantly improve BMD in older women when compared with the control group (p>0.05).

Table 4. Final test results for the study groups

	Pilates group (n=13)			Control group (n=10)			
Final test	**Mean (95% CI)**	**Range**	**pPG**	**Mean (95% CI)**	**Range**	**pCG**	**p**
BMI ($kg.m^{-2}$)	30.3 (27.3-33.3)	21.4-36.3	0.09	29.7 (26.8-32.6)	24.5-37.5	0.66	0.76
Fat ratio(%)	38.2 (34.7-41.7)	24.5-45.0	**0.01**	37.3 (31.8-42.9)	18.4-46.4	0.18	0.62
FFM (kg)	42.8(41.0-44.6)	37.4-48.5	**0.01**	44.6 (32.8-46.5)	40.1-47.9	0.66	0.19
WC (cm)	85.5 (80.3-80.6)	69.0-95.0	**0.01**	93.8 (88.9-98.7)	85.0-102.0	0.32	**0.04**
HC (cm)	106.8 (101.4-112.2)	92.0-123.0	**0.03**	109.4 (102.8-116.0)	96.0-123.0	0.56	0.58
		SPPB (scores)					
Balance	4.00 (4.00-4.00)	4.00-4.00	**0.02**	3.90 (3.67-4.12)	3.00-4.00	0.32	0.25
4 m walk	4.00 (4.00-4.00)	4.00-4.00	0.08	2.20 (1.09-3.30)	0.00-4.00	**0.05**	**0.05**
Sit-to-stand	3.77 (3.50-4.03)	3.00-4.00	1.00	2.50 (1.47-3.52)	0.00-4.00	**0.03**	**0.02**
Total score	11.8(11.5-12.0)	11.0-12.0	**0.02**	8.60 (6.74-10.4)	4.00-12.0	**0.04**	**0.01**
		BMD ($g.cm^{-2}$)					
L1-L4 Tscore	-0.57 (-1.36-0.22)	-2.20-2.10	0.61	-1.08 (-1.85 to -0.30)	-2.80-0.40	0.52	0.51
L1-L4 Zscore	0.80 (0.12-1.47)	-1.10-2.60	0.29	-0.01 (-1.07-1.05)	-3.40-2.00	0.62	0.14
L1-L4 BMD	1.12 (0.96-1.27)	0.87-1.79	0.27	1.08 (0.85-1.31)	0.80-1.93	0.77	0.54
Femur n. Tsco.	-1.20 (-1.50 to -0.89)	-2.00 to -0.10	0.31	-1.07 (-1.99 to -0.14)	-2.40-1.80	0.55	0.69
Femur n. Zsco.	0.32 (0.02-0.62)	-0.30-1.20	0.30	0.12 (-0.49-0.73)	-0.90-2.00	0.17	0.37
Femur n. BMD	0.82 (0.78-0.85)	0.72-0.95	0.28	0.79 (-8.56-25.0)	0.68-1.01	0.16	0.29
Total Tscore	-1.02 (-1.64 to -0.38)	-3.30 to -0.10	0.84	-0.68 (-1.67-0.31)	-2.20-1.90	0.68	0.88
Total Zscore	0.31 (-0.08-0.69)	-1.20-1.30	0.79	0.52 (-0.36-1.40)	-0.90-2.60	0.93	0.69
Total BMD	0.91 (0.84-0.96)	0.66-0.99	0.89	0.90 (0.80-1.04)	0.75-1.23	0.65	0.54

Figures as means (95% CI). CI: confidence interval; BMI: body mass index; FFM: fat free mass; HC: hip circumference; WC: waist circumference; BMD: bone mineral density; SPPB: short physical performance battery. pPG: difference within Pilates group; pCG: difference within control group; p: difference between groups after the exercise period.

The Pilates group improved significantly in terms of fat ratio (p=0.005), FFM (p=0.008), WC (p=0.007), HC (p=0.028), balance (p=0.014) and in the SPPB total score (p=0.013, p<0.05). In the control group, there were significant decreases in 4m walk test performance (p=0.041), sit to stand test score (p=0.025), and total physical performance score (p=0.039, p<0.05).

DISCUSSION

As a main finding, the improvement in BMI and BMD was not statistically significant. However, fat ratio, fat-free mass, waist and hip circumference, balance and total physical performance improved significantly in the Pilates group when compared with baseline. Walking test performance, sit-stand test score and total physical performance score declined in the CG.

If the bone is under sufficient mechanical stress, remodeling is promoted (23). However, different results may be obtained in older adults due to individual differences in bone remodeling. Pilates exercise did not change T-, Z- and BMD-scores of postmenopausal elderly women who participated in the study. However, BMD average scores were higher than before. Although no supplements were taken, BMD increased on average. Our findings are consistent with some studies reporting that the effect of exercise on BMD is not significant (24,25). This finding may indicate that, short-term Pilates does not produce a resistance exercise effect on the BMD of postmenopausal women.

Angin et al. reported that Pilates exercises significantly increased BMD. It is thought that the different finding in their study may be due to the fact that they included younger women with osteoporosis (40-69 years), and that it was a six month long study (18). According to a newly published meta-analysis, the effect of Pilates exercises on BMD in postmenopausal women is unclear. However, the small number of studies included in the review and the low methodological quality of the majority of the studies do not currently allow reliable estimation of results. More robust randomized controlled studies with high methodological quality are needed to confirm the results of this meta-analysis (21)

One-third of all adults over the age of 64 is faced with a risk of falling every year (26). When older adults experience concerns about falling, physical activity levels decrease and cause limited daily activities. Exercise improves muscle strength of core and postural stability to prevent falls (27). Keasler et al. found that Pilates and balance exercises may improve postural stability in older adults (28). According to another study, reformer exercises significantly improve-functional movement, static and dynamic balance (29). Some of the studies supported that Pilates exercise and dance provide an improvement in balance of older adults (30,31). In our study, the PG group demonstrated a significant improvement ($p<0.05$) for balance. Therefore, it can be emphasized that the result obtained from our study supports the expected effect from Pilates.

According to the secondary findings, the PG group demonstrated a significant improvement ($p<0.05$) for waist circumference, walking speed (4m walk), leg strength (sit to stand), and total physical performance in older women when compared with the control group ($p>0.05$, Table 4). Thus, it is possible to state that a hypothesis of the research is confirmed, and Pilates is effective on physical performance. Interestingly, it's important to emphasize that there was a significant decrease in the CG ($p<0.05$). Phrompaet et al., who examined the effects of Pilates exercises on flexibility and lumbo-pelvic movement control reported that the flexibility of the Pilates group increased significantly compared with the control group (32).

Pilates improved significantly fat ratio, FFM, WC, HC ($p<0.05$), but there was no effect on BMI. ($p>0.05$, Table 4). In the control group, no significant difference in body composition variables was present after the program ($p>0.05$). Fourie et al. (33), and Sekendiz et al., (34) found insignificant changes in BMI. Older adults who have sedentary lifestyles lose fat-free mass faster than people who have regular exercise routine (35). Accordingly, it was similar to the findings of Ruiz-Montero et al., with improved basic muscle mass and decreased FM values with aerobic and Pilates exercises (36), and of Lomba Vasconcelos et al. on waist and hip measurements in older women (37).

There are some limitations in our study. First is the number of participants. The reason for this is the limited number of participants who can regularly take part in an exercise program, and adherence to exercise in terms of health in this age group. Second, we did not investigate the effects of the frequency and intensity of exercise on BMD. We assessed BMD again after three months of exercise.

CONCLUSION

Pilates exercise have effects on body composition and physical performance of older women. BMD did not significantly increase; however, the mean values were higher in the Pilates group. It is possible to say that short-term Pilates exercise does not produce a resistance training effect on bone mineral density of postmenopausal women.

Ethics Committee Approval / Etik Komite Onayı

The study was approved by the Ethics Committee of Çanakkale Onsekiz Mart University (Date: 013.03.2019, Decision no: 2019-06).

Conflict of Interest / Çıkar Çatışması

The authors declared no conflicts of interest with respect to authorship and/or publication of the article.

Financial Disclosure / Finansal Destek

The research was supported by the Çanakkale Onsekiz Mart University Scientific Research Projects Commission (Project ID: 2925).

Author Contributions / Yazar Katkıları

Concept:KSB,GŞ; Design: GŞ,CZ; Supervision: GŞ,CZ; Materials: KSB,GŞ; Data Collection and/or Processing: GŞ,AC; Analysis and Interpretation: KSB,GŞ,AC; Literature Review: KSB,GŞ; Writing Manuscript: GŞ,CZ; Critical Reviews: GŞ,CZ.

REFERENCES

1. Lindsey C, Brownbill RA, Bohannon RA, Ilich JZ. Association of physical performance measures with bone mineral density in postmenopausal women. *Arch Phys Med Rehabil.* 2005;86(6):1102-07.
2. Marques EA, Mota J, Carvalho J. Exercise effects on bone mineral density in older adults: a meta-analysis of randomized controlled trials. *Age (Dordr).* 2012;34(6):1493-515.
3. Johnell O, Kanis J. Epidemiology of osteoporotic fracture. *Osteoporosis Int.* 2005;16(Suppl 2):S3-7.
4. Lanyon L, Skerry T. Postmenopausal osteoporosis as a failure of bone's adaptation to functional loading: a hypothesis. *J Bone Miner Res.* 2001;16(11):1937-47.
5. Gordon JL, Eisenlohr-Moul TA, Rubinow DR, Schrubbe L, Girdler SS. Naturally occurring changes in estradiol concentrations in the menopause transition predict morning cortisol and negative mood in perimenopausal depression. *Clin Psychol Sci.*2016;4(5):919-35.
6. Schwab P, Scalapino K. Exercise for bone health: rationale and prescription. *Curr Opin Rheumatol.* 2011;23(2):137-41.
7. Chilibeck PD, Sale DG, Webber CE. Exercise and bone mineral density. *Sports Med.* 1995;19(2):103-22.
8. Kohrt WM, Ehsani AA, Birge Jr SJ. Effects of exercise involving predominantly either joint–reaction or ground–reaction forces on bone mineral density in older women. *J Bone Miner Res.* 1997;12(8): 1253-61.
9. Kemmler W, Engelke K, Weineck J, Hensen J, Kalender WA. The Erlangen Fitness Osteoporosis Prevention Study: a controlled exercise trial in early postmenopausal women with low bone density-first year results. *Arch Phys Med Rehabil.* 2003;84(5):673-82.
10. Toraman F, Şahin G. Age responses to multicomponent training programme in older adults. *Disabil Rehabil.* 2004;26(8):448-54.
11. Iwamoto J, Suzuki H, Tanaka K, Kumakubo T, Hirabayashi H, Miyazaki Y, et al. Preventative effect of exercise against falls in the elderly: a randomized controlled trial. *Osteoporosis Int.* 2009;20(7): 1233-40.
12. Peterson MJ, Giuliani C, Morey MC, Pieper CF, Evenson KR, Mercer V, et al. Physical activity as a preventative factor for frailty: the health, aging, and body composition study. *J Gerontol A Biol Sci Med Sci.* 2009;64(1):61-8.
13. Zhao R, Zhang M, Zhang Q. The effectiveness of combined exercise interventions for preventing postmenopausal bone loss: a systematic review and meta-analysis. *J Orthop Sports Phys Ther.* 2017;47(4):241-51.
14. Chodzko-Zajko WJ, Proctor DN, Fiatanore Singh MA, Minson CT, Nigg CR, Salem GJ, et al. American College of Sports Medicineposition stand: Exercise and physical activity for older adults. *Med Sci Sports Exerc.* 2009;41(7):1510-30.
15. Burton E, Farrier K, Lewin G, Pettigrew S, Hill AM, Airey P, et al. Motivators and barriers for older people participating in resistance training: a systematic review. *J Aging Phys Act.* 2017;25(2):311-24.
16. Smith K, Smith E. Integrating Pilates-based core strengthening into older adult fitness programs implications for practice. *Topics Geriatr Rehabil.* 2005;21(1):57-67.
17. Johnson EG, Larsen A, Ozawa H, Wilson CA, Kennedy KL. The effects of Pilates-based exercise on dynamic balance in healthy adults. *J Bodywork Mov Ther.* 2007;11(3):238-42.
18. Angin E, Erden Z, Can F. The effects of clinical pilates exercises on bone mineral density, physical performance and quality of life of women with postmenopausal osteoporosis. *J Back Musculoskelet Rehabil.* 2015;28(4):849-58.
19. Kelley GA, Kelley KS. Dropouts and compliance in exercise interventions targeting bone mineral density in adults: a meta-analysis of randomized controlled trials. *J Osteoporos.* 2013:250423.
20. Cohen-Mansfield J, Marx MS, Guralnik JM. Motivators and barriers to exercise in an older community-dwelling population. *J Aging Phys Act.* 2003;11(2):242-53.
21. Gonçalves de Oliveira R, Ueno Anami GE, Aparecida Coelho EA, Campos de Oliveira L. Effects of Pilates exercise on bone mineral density in postmenopausal women: a systematic review and meta-analysis. *J Geriatr Phys Ther.* 2022;45(2):107-14.
22. Guralnik JM, Simonsick EM, Ferrucci L. Glynn RJ, Berkman LF, Blazer DG, et al. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. *J Gerontology.* 1994;49(2):M85-94.
23. Hsieh YF, Robling AG, Ambrosiu WT, Burr DB, Turner CH. Mechanical loading of diaphyseal bone in vivo: the strain threshold for an osteogenic response varies with location. *J Bone Miner Res.* 2001;16(12):2291-7.
24. Mikalacki M, Cokorilo N, Obradovic B, Ana Marijanac A, Ruiz-Montero PJ. Effects of Pilates-interventional program on calcaneus-bone density parameters of adult women. *Int J Morphol.* 2015;33(4):1220-24.
25. Sabatini Gandolfi NR, Corrente JE, De Vitta A, Gollino L, Ferrerio da Silva Mazeto GM. The influence of the Pilates method on quality of life and bone remodelling in older women: a controlled study. *Qual Life Res.* 2020;29(2):381-9.
26. Sattin RW. Falls among older persons: a public health perspective. *Annu Rev Public Health.* 1992;13: 489-508.
27. Campbell AJ, Robertson MC, Gardner MM, Norton RN, Tilyard MW, Buchner DM. Randomised controlled trial of a general practice programme of home based exercise to prevent falls in elderly women. *BMJ.* 1997;315(7115):1065-9.
28. Kaesler DS, Mellifont RB, Kelly PS, Taaffe DR. A novel balance exercise program for postural stability in older adults: a pilot study. *J Bodyw Mov Ther.* 2007;11(1):37-43.
29. Roller M, Kachingwe A, Beling J, Ickes DM, Cabot A, Shrier G. Pilates reformer exercises for fall risk reduction in older adults: a randomized controlled trial. *J Bodyw Mov Ther.* 2018;22(4):983-98.
30. Bird ML, Fell J. Positive long-term effects of Pilates exercise on the age-related decline in balance and strength in older, community-dwelling men and women. *J Aging Phys Act.* 2014;22(3):342-7.
31. Filar-Mierzwa K, Długosz-Boś M, Marchewka A, Aleksander-Szymanowicz P. Effect of different forms of physical activity on balance in older women. *J Women Aging.* 2021;33(5):487-502.
32. Phrompaet S, Paungmali A, Pirunsan U, Sitilertpisan P. Effects of Pilates training on lumbo-pelvic stability and flexibility. *J Sports Med.* 2011;2(1):16-22.
33. Fourie M, Gildenhuys GM, Shaw I, Shaw BS, Toriola AL, Goon DT. Effects of a mat Pilates programme on body composition in elderly women. *West Indian Med J.* 2013;62(6):524-8.
34. Sekendiz B, Altun Ö, Korkusuz F, Akın S. Effects of Pilates exercise on trunk strength, endurance and flexibility in sedentary adult females. *J Bodyw Mov Ther.* 2007;11(4):318-26.
35. Frontera WR, Hughes VA, Lutz KJ, Evans WJ. A cross-sectional study of muscle strength and mass in 45- to 78-yr-old men and women. *J Appl Physiol (1985).* 1991;71(2):644-50.
36. Ruiz-Montero PJ, Castillo-Rodriguez A, Mikalački M, Nebojsa C, Korovljev D. 24-weeks Pilates-aerobic and educative training to improve body fat mass in elderly Serbian women. *Clin Interv Aging.* 2014;9:243-8.
37. Lomba Vasconcelos APS, Correia Cardozo D, Granero Lucchetti AL, Lucchetti G. Comparison of the effect of different modalities of physical exercise on functionality and anthropometric measurements in community-dwelling older women. *J Bodyw Mov Ther.*2016;20(4):851-6.