ISSN: 2651-4451 • e-ISSN: 2651-446X

Turkish Journal of Physiotherapy and Rehabilitation

2024 35(3)361-372

Büşra KALKAN BALAK, PhD, PT[1]
Zeliha Özlem YÜRÜK, PhD, PT[2]

1 Physical Therapy and Rehabilitation Department, Faculty of Health Sciences, Yuksek Ihtisas University, Ankara, Türkiye.
2 Physical Therapy and Rehabilitation Department, Faculty of Health Sciences, Baskent University, Ankara, Türkiye.

Correspondence (İletişim):

Büşra KALKAN BALAK, PhD, PT1
Yuksek Ihtisas University,
Faculty of Health Sciences, Physical Therapy and Rehabilitation Department
Oguzlar Neighborhood, 1375th Street No:8, 06520, Balgat Campus, Ankara, Türkiye.
E-mail: busrakalkanbalak@gmail.com
ORCID: 0000-0002-4428-5752

Zeliha Özlem YÜRÜK
E-mail: bastug@baskent.edu.tr
ORCID: 0000-0002-4408-6489

Received: *15.08.2023 (Geliş Tarihi)*
Accepted: *20.10. 2024 (Kabul Tarihi)*

EFFECTS OF PILATES EXERCISES AND WHOLE-BODY VIBRATION EXERCISES TRAINING ON BODY COMPOSITION, FLEXIBILITY, AND BALANCE IN HEALTHY WOMEN: RANDOMIZED CONTROLLED PILOT STUDY

ORIGINAL ARTICLE

ABSTRACT

Purpose: This study aims to compare the effects of pilates and whole-body vibration exercise training on body composition, flexibility, balance, and functional strength of core muscles in healthy women.

Methods: Thirty-six healthy women were divided into three groups: a pilates group, a whole-body vibration (WBV) exercise group, and a control group. The pilates group received training using the 'Reformer®,' while the WBV group used the 'Power Plate®.' Both groups trained twice a week for eight weeks, with sessions lasting 45-60 minutes each. The control group did not receive any training. Body composition was assessed using body mass index (BMI), the waist-to-hip ratio, and bioelectrical impedance analysis. Sit-and-Reach Test for flexibility, Functional Reach Test for balance, and Sit-ups and Modified Push-ups Test for core muscle strength. Assessments were made before and after training.

Results: In the group comparisons, significant differences in BMI and some bioelectrical impedance parameters were observed in the WBV group (p<0.05). However, no significant changes in body composition were found in the pilates and control groups and no difference was found between the three groups (p>0.05). Flexibility showed significant differences among the three groups (p<0.01). Functional core strength increased in both the pilates and WBV groups (p<0.05), but no significant differences were observed in balance and strength comparisons between the groups (p>0.05).

Conclusion: Results indicate that WBV training affected body composition, and both exercise groups improved flexibility, balance, and core strength. However, WBV was not superior to pilates. Further research is needed for generalizability.

Keywords: Balance, Body composition, Core muscles, Exercise, Physiotherapy and Rehabilitation.

SAĞLIKLI KADINLARDA PİLATES EGZERSİZLERİ VE TÜM VÜCUT VİBRASYON EGZERSİZ EĞİTİMİNİN VÜCUT KOMPOZİSYONU, ESNEKLİK VE DENGE ÜZERİNDEKİ ETKİLERİ: RANDOMİZE KONTROLLÜ PİLOT ÇALIŞMA

ARAŞTIRMA MAKALESİ

ÖZ

Amaç: Bu çalışmanın amacı sağlıklı kadınlarda pilates ve tüm vücut vibrasyon egzersizlerinin vücut kompozisyonu, esneklik, denge ve çekirdek kasların fonksiyonel gücü üzerine etkilerini karşılaştırmaktır.

Yöntem: Otuz altı sağlıklı kadın üç gruba ayrıldı: Pilates grubu, Tüm Vücut Vibrasyon (TVV) grubu ve kontrol grubu. pilates grubu "Reformer®" kullanarak eğitim alırken, TVV grubu "Power Plate®" kullandı.Her iki grup da sekiz hafta boyunca haftada iki kez 45-60 dakika eğitim aldı. Kontrol grubu ise herhangi bir eğitim almadı. Katılımcıların vücut kompozisyonu; vücut kütle indeksi, bel-kalça oranı ve biyoelektriksel impedans analizi ile değerlendirildi. Esneklik için "otur-uzan testi", denge için "fonksiyonel uzanma testi", çekirdek kas kuvveti için ise “sit-ups ve modifiye push-ups testi” uygulandı. Değerlendirmeler eğitim öncesi ve sonrasında yapıldı.

Sonuçlar: Gruplar arası karşılaştırmalarda, TVV grubunun vücut kütle indeksi ve bazı bioelektriksel impedans analiz parametrelerinde istatistiksel olarak anlamlı farklar gözlendi (p<0,05). Pilates grubu ve kontrol grubunda ise vücut kompozisyonu verilerinde anlamlı farklar görülmedi ve üç grup arasında fark bulunmadı (p>0,05). Esneklik açısından ise üç grup arasında istatistiksel olarak anlamlı fark saptandı (p<0,01). Çekirdek kaslarının fonksiyonel kuvveti hem Pilates grubunda hem de TVV grubunda arttı (p<0,05), ancak hiçbir grup için karşılaştırmalarda denge ve fonksiyonel kuvvet açısından istatistiksel fark bulunmadı (p>0,05).

Tartışma: Sonuçlar, TVV egzersiz eğitiminin vücut kompozisyonu etkilediği, esneklik, denge ve kor kaslarının fonksiyonel kuvvetini artırmada her iki eğitim grubunun da etkili olduğu ancak TVV egzersiz eğitiminin Pilates egzersiz eğitimine üstünlüğü olmadığını göstermektedir. Bu sonuçların genellenebilirliğini değerlendirmek için daha fazla araştırmaya ihtiyaç duyulmaktadır.

Anahtar Kelimeler: Denge, Vücut Kompozisyonu, Kor Kasları, Egzersiz, Fizyoterapi ve Rehabilitasyon.

INTRODUCTION

The World Health Organization (WHO) defines health as "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity." In contemporary times, the essence of a healthy lifestyle involves maintaining both physical and mental activity, adopting a balanced and nutritious diet, refraining from smoking and excessive alcohol consumption, and effectively managing stress (1).

In recent years, various factors such as desk-bound work and technology addiction have contributed to sedentary lifestyles. Sedentary living represents a significant global issue, with adverse impacts on societies, including weight gain and an escalation of chronic ailments. Recent global estimates indicate that 1.4 billion adults, representing 27.5% of the world's adult population, fail to meet the recommended levels of physical activity for improving and maintaining their health (2). Consequently, enhancing physical activity is pivotal to averting chronic diseases and promoting healthy aging. Participating in exercise and sports remains the most effective approach to heighten physical activity levels (3).

Pilates and whole-body vibration (WBV) training have emerged as prominent and intriguing exercise methodologies in recent times. The pilates method, developed by American physical trainer Joseph Hubertus Pilates (1880-1967) in New York, represents a fusion of balance, breathing, and movement systems founded on the symbiosis of mind and body. As pilates emphasizes the role of cognitive control over muscles, it is often termed "Contrology." Executed at a deliberate pace and demanding mental engagement, pilates movements prioritize both the activation of "core" muscles and the precision and command of the executed motions (4).

WBV constitutes a neuromuscular training technique involving the application of mechanical stimulation through systemic vibration signals. For numerous years, low-amplitude, low-frequency vibration has been advocated as a beneficial adjunct to exercise for enhancing physical fitness (5). In WBV, mechanical and sinusoidal vibrations are transmitted through a platform beneath the feet to the entire body. WBV facilitates static and dynamic exercises alike and finds applications in physiotherapy as well as among professional athletes. Multiple studies have demonstrated that WBV can enhance muscular strength, flexibility, and bone density, while concurrently refining proprioception and balance (5,6).

WBV and pilates training have gained significant popularity as methods implemented in wellness centers in recent years. While several studies have demonstrated the impact of these individual methods, there exists only a solitary study that directly contrasts them (7). This particular study focused on post-menopausal women and revealed that both WBV and Pilates training hold equal efficacy in preserving mineral bone density. Nonetheless, beyond this specific investigation, a dearth of research exists comparing the influences of these training approaches on aspects such as body composition, flexibility, and balance.

The aim of this study is to comprehensively compare the effects of both Pilates exercises and Whole-Body Vibration training on body composition, flexibility, balance, and functional strength of core muscles among healthy individuals, who commonly resort to these methods for physical appearance enhancement. For this purpose, three different hypotheses have been formulated in our study to investigate whether both types of training have an effect on the researched parameters and to examine whether one has superiority over the other.

METHODS

Subjects

In this research, a randomized-control study design was employed. Our study was conducted on sedentary women who applied to a private Health Center in Ankara, Turkey between August 2018 and December 2018, did not have any health problems, and voluntarily agreed to participate in the study.

Inclusion Criteria:

• Individuals aged between 25-45 years.

• Individuals who had not engaged in regular exercise over the preceding six months.

• Individuals with a moderate level of physical ac-

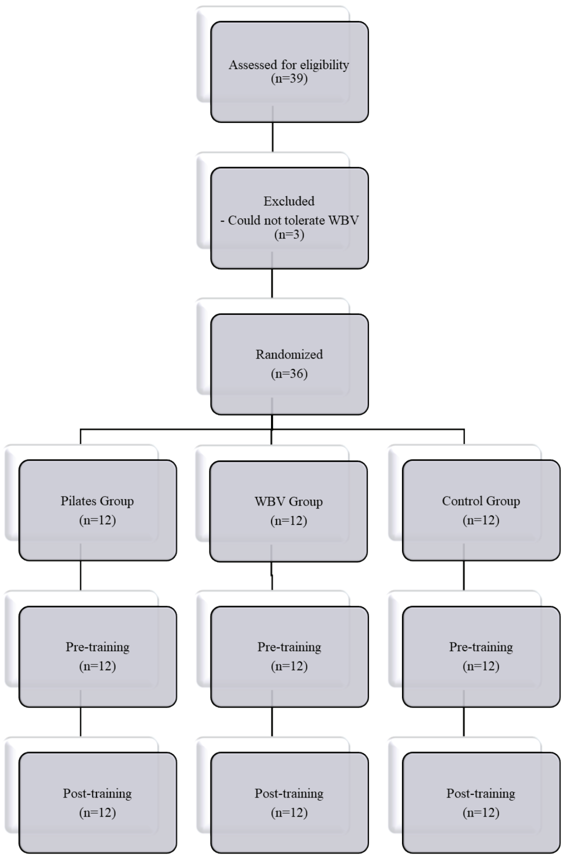

Figure 1. Flow Chart of the Study

tivity moderate level ranging from 600 to 3000 MET minutes/week (Metabolic Equivalent minutes/week), as assessed using the "International Physical Activity Questionnaire".

• Individuals with a body weight below 130 kg.

Exclusion Criteria:

• Individuals with a history of malignancies.

• Pregnant individuals.

• Individuals afflicted with musculoskeletal pain stemming from orthopedic or rheumatic conditions.

• Individuals with a recent history of fractures within the past year.

• Individuals diagnosed with neurological disorders (e.g., stroke, epilepsy).

• Individuals with chronic kidney or liver ailments.

• Individuals with cardiovascular conditions (e.g., cardiac arrhythmia, cardiac insufficiency).

• Individuals suffering from imbalance linked to a peripheral vestibular disorder diagnosis (such as Benign Paroxysmal Positional Vertigo or Meniere's disease).

• Individuals' incapable of tolerating WBV for more than five minutes.

This study was carried out with the requisite authorization from the Başkent University Medical and Health Sciences Research Board and Non-Invasive Clinical Research Ethics Board (approval date: 19/09/2018, reference: KA18/268). Additionally, written informed consent was obtained from all participants before their enrollment in the study.

Sample Size Calculation: Prior to initiating the study, a sample size and power analysis was performed using G* power software. Based on the "primary measurement" of "body fat ratio," an appropriate sample size was determined to achieve 90% statistical power with a 0.05 margin of error. Consequently, an initial total of 30 subjects were established, with an allocation of 10 subjects in each group. To account for a potential data loss of

20% during the study, the sample size was adjusted with a 20% surplus. Therefore, the final number of participants in the study was determined to be 36, with each group consisting of 12 subjects (8). After the study, analyses based on body fat percentage, which is also a product measurement, revealed significant differences between the groups at 98% power and 0.05 significance level.

Before starting the study, the subjects were asked to stay in a slight squat position without moving for 30 seconds to test whether they could tolerate WBV. Subjects who could tolerate it were randomly divided into three groups using the "Random Online Allocation Software" (www.Graphpad.com) (Figure 1).

Group 1: Pilates training group

Group 2: WBV exercises training group

Group 3: Control group

Outcome Measures

The subjects taking part in the study were assessed before starting the training program and at the end of the 8-weeks program.

The following assessment parameters were employed in the study:

• Sociodemographic variables

• Physical activity level

• Body composition

• Flexibility

• Balance

• Functional strength of core muscles

Sociodemographic Variables

Data encompassing sociodemographic aspects such as age, weight, height, education level, and occupation were gathered at the initiation of the study.

Physical Activity Level

The abbreviated version of the "International Physical Activity Questionnaire" in Turkish was administered to study participants to ascertain their physical activity levels, as stipulated by the inclusion criteria, and to confirm their moderate level of physical activity.

This concise form encompasses seven questions and elucidates factors including sitting duration, walking, activities of moderate intensity, and time allocated to vigorous activities. In terms of scoring, individuals are categorized as follows: those with <600 MET-min/week are regarded as physically inactive, those with 600-3000 MET-min/week demonstrate a low physical activity level, and those with >3000 MET-min/week possess a satisfactory level of physical activity. Individuals with a weekly physical activity score within the range of 600-3000 MET-min/week (moderate level) were eligible for inclusion in our study (9, 10).

Body Composition

The study employed Body Mass Index (BMI), waist-hip ratio, and bioimpedance analysis to ascertain body composition.

Body Mass Index (BMI)

Calculated as the weight in kilograms divided by the square of the height in meters. The height measurement was conducted using a stadiometer, which is a standard measurement method. (11).

Waist-Hip Ratio

Waist circumference was measured over the umbilicus and at the lowest costal level, while hip circumference was measured at the widest point of the posterior hip. These measurements were then proportionally related to each other (12).

Bioimpedance Analysis (BIA)

The Tanita BC 601 device (Tanita Corp., Maeno-Cho, Tokyo, Japan) was employed to quantify body fat and muscle proportions for assessing body composition. This professional body analysis instrument incorporates eight polar electrodes, with two electrodes allocated to each limb. Utilizing a 50 kHz, 0.8 mA electric current, the device measures the body's resistance during the current's passage through tissues. This process enables the determination of fat and muscle quantities. During BIA measurements, participants were instructed to wear lightweight attire.

Participants were directed to stand on the device's plantar electrodes with bare feet and to grasp the hand-held component of the apparatus with flexed elbows. Upon the completion of measurements, data encompassing muscle weight, fat weight, fat percentage, and lean mass were documented by generating a printout from the device (12,13).

Flexibility

Flexibility is divided into two categories: static and dynamic. Dynamic flexibility is associated with sports and is difficult to measure. Therefore, flexibility is generally evaluated statically (14, 15). Evaluation can be done through direct or indirect methods. In direct evaluation, instruments such as a goniometer, flexometer, or inclinometer are used. The reliability and validity of direct measurement depend on the skill of the evaluator and the joint being measured. The commonly used indirect measure of flexibility is the Sit and Reach Test. While it does not reflect overall body flexibility, it evaluates hamstring, gastrocnemius and lower back flexibility. Therefore, the "Sit and Reach Test" was used to assess flexibility. This evaluation involved the use of a sit and lie board measuring 30 cm in height, 45 cm in width, and 100 cm in length. The reference point "0" was designated at the 25 cm inner section of the sit and reach board, where participants positioned their feet. The region closer to the individual from this reference point represented negative values, while the farther side indicated positive values. Individuals were acquainted with the test and instructed to perform two trials. During the test, participants were guided to prevent knee bending by applying pressure to their knees. Subsequently, they were prompted to extend their fingertips to the furthest point attainable and sustain this position for two seconds. The test was repeated thrice, and the average of the measurements in centimeters was documented (16,17).

Balance

To evaluate the functional balance of participants, the "Functional Reach Test" was administered. This assessment commenced by instructing the individual to extend their arm directly forward, recording the achieved distance. Subsequently, participants were tasked with reaching as far forward as possible without lifting their heels off the ground. The maximum distance attainable without compromising balance was marked. This process was reiterated thrice, and the average measurement was computed (18-20).

Functional Strength of Core Muscles

Functional strength of core muscles was evaluated with 'sit-ups and modified push-ups' tests (21,22).

Sit-ups Test: Individuals were asked to perform trunk flexion with knees in flexion position and feet in the position determined by the physiotherapist.

Figure 2. Pilates Exercise (Feet in Straps) and WBV Exercise (Squat) Examples

The number of movements that individuals could make for 30 seconds was recorded.

Modified Push-ups Test: Individuals were positioned in a prone position, hands at shoulder level, elbows flexed, next to the body. Individuals were asked to lift their head, shoulders and trunk off the ground with the elbows in full extension. During the test, the knees were positioned in flexion. The number of movements that individuals could make for 30 seconds was recorded.

Intervention

The implementation of Pilates and WBV exercises training was conducted by a trained physiotherapist (Figure 2). Before each session, participants in both training groups engaged in a series of warm-up activities (with roll down, side stretch, toy soldier stretch and saw), encompassing a single set of 10 repetitions and 10 minutes of stretching exercises targeting major muscle group throughout the body. Subsequently, cool-down exercises (static hip adductor muscle group stretching, hip flexor stretching, hamstring stretching, trunk lateral flexors stretching) were administered for 10 minutes at the session's conclusion. To maintain consistency, individuals within each group were advised not to partake in any additional training or dietary programs without informing the therapist.

Pilates Training: Clinical Pilates training was administered to the first group employing the "Reformer®" device for eight weeks, comprising two non-consecutive days per week, with each session lasting 45 minutes. The initial session encompassed an explanation of postural awareness and the fundamental principles of the Pilates method. The physiotherapist provided primary demonstrations of the exercises, accompanied by visual imagery. Over the course of training, participants were encouraged to focus on Pilates' foundational principles. The physiotherapist meticulously monitored and adjusted the exercises, offering tactile and verbal cues for corrections.

In subsequent weeks, starting with a single set of 10 repetitions, gradual adjustments were made with increases in the exercise position, spring resistance (yellow, green, blue and red) and the number of sets and repetitions, in which the individual stated that she did not have difficulty in the sets and number of sets. The exercise repertoire included activities such as foot work, tendon stretch, bridge, supine arm work, and long and short box series (4,23).

WBV Exercises Training: The second group participated in WBV exercises training utilizing the "Power Plate® pro5™ (71-PR5-3100-Performance Health Systems, LLC)" device for eight weeks, twice weekly on non-consecutive days, and each session lasting 40 minutes. This training entailed standing on the platform of the device. Initial exercises involved becoming accustomed to the vibrations, followed by a series of upper and lower extremity activities. These exercises encompassed various movements like lunges, squats, calf raises, and planks targeting different extremities. Studies have shown that high frequency vibration increases the activities of the lower extremity muscles more, so high frequency was used in the lower extremities (24,25). Training frequencies of 35 Hz for upper extremities and 50 Hz for lower extremities, alongside an amplitude of 3 mm, were employed. The training protocol evolved over the weeks, beginning with 30-second exercise sets for the first 1-3 weeks, extending to 45 seconds for weeks 4-6, and ultimately reaching 60 seconds for weeks 6-8, with the specific number of sets tailored to each individual. When individuals expressed that they did not feel fatigued when performing exercises and could tolerate longer durations, the duration of the exercise was increased. A 30-second inter-set break was observed (26).

Control Group: No specific training was provided to the control group. These participants were advised not to partake in any exercise or diet programs without informing the therapist and were encouraged to continue their regular daily activities. At the end of the study, individuals in the control group were included in the other groups they wished to participate in.

Statistical Analysis

The statistical package for social sciences (SPSS) version 20.0 was employed for the statistical analyses of this study (IBM SPSS Statistics for Windows, Armonk, NY: IBM Corp.). The concordance of the variables with normal distribution was analyzed be means of the Shapiro-Wilk test. For variables de-

Table 1. Physical and Sociodemographic Characteristics of Individuals.

	Pilates Group (n=12)	WBV Group (n=12)	Control Group (n=12)	p
Age (years), X±SD	34.16 ± 8.83	33.25 ± 8.13	28.08 ± 6.00	0.050
Body weight (kg), X±SD	62.41 ± 8.66	65.98 ± 7.16	63.30 ± 12.03	0.200
BMI (kg/m²), X±SD	23.88 ± 4.40	24.67 ± 2.79	23.44 ± 4.14	0.200
Educational Status, n (%)				
Postgraduate	1 (8.3)	2 (16.7)	0 (0)	**0.001**
University	8 (66.7)	6 (50)	8 (66.7)	
High school	3 (25)	4 (33.3)	3 (25)	
Primary education	0 (0)	0 (0)	1 (8.3)	
Profession, n (%)				
Working	5 (41.7)	5 (41.7)	8 (66.7)	**0.000**
Housewife	4 (33.3)	4 (33.3)	0 (0)	
Not working	3 (25)	3 (25)	4 (33.3)	

* p <0.05, p Statistical significance value of comparison between groups (Kruskal Wallis Test), X: Average, SD: Standard Deviation, n: Number, %: Percent, kg: Kilogram, m²: Square meter, WBV: Whole Body Vibration, BMI: Body Mass Index.

termined by measuring, average ± standard deviation (X ± SD) was calculated, whereas percentage (%) values were calculated for values determined by counting. Wilcoxon test was used to compare the pre- and post-training values of the groups. Kruskal Wallis test was used to compare the three groups. Mann-Whitney U Test was used to compare the groups two by two. The significance value was accepted to be p<0.05, whereas the level of significance used for triple testing was p<0.017 for Bonferroni correction purposes. The effect size (ES) was calculated according to the formula "r=z/√N" using the Z score of the Wilcoxon test (27). An ES value of 0.1-0.3 was accepted as "low", whereas 0.3-0.5 and >0.5 were accepted as "moderate" and "high", respectively (28).

RESULTS

Descriptive characteristics of the study participants are presented in Table 1. Notably, all descriptive features of the individuals were largely consistent, barring disparities in educational background and occupation, where no statistically significant differences were observed (p> 0.05). Examination of body composition data before and after training revealed no significant differences within any

Table 2. Comparison of Findings Related to Body Composition.

	Pilates Group (n=12) (X±SD)			WBV Group (n=12) (X±SD)			Control Group (n=12) (X±SD)			p²
	BT	AT	p¹	BT	AT	p¹	BT	AT	p¹	
BMI (kg/m²)	23.88±4.40	23.52±4.03	0.530	24.67±2.79	24.07±2.65	**0.010***	23.44±4.14	23.70±4.24	0.270	0.970
ES	0.120			0.520			0.220			
Waist-Hip Ratio (cm)	0.74±0.04	0.73±0.04	0.720	0.73±0.04	0.73±0.05	0.870	0.73±0.05	0.73±0.05	1.000	0.990
ES	0.070			0.030			0.000			
Muscle Weight (kg)	41.88±3.28	41.59±3.19	0.420	42.81±2.05	42.36±2.14	**0.040***	42.35±4.23	42.45±4.61	093.	0.810
ES	0.160			0.410			0.010			
Fat weight (kg)	18.50±6.44	17.63±5.45	0.230	20.91±5.55	19.78±5.68	**0.010***	18.69±8.48	19.41±8.22	0.130	0.490
ES	0.240			0,510			0,300			
Fat Percentage (%)	28.80±7.49	28.17±6.32	0.280	31.18±5.68	30.11±6.36	**0.030***	28.26±8.28	29.15±7.48	0.350	0.630
ES	0.210			0.420			0.190			
Lean Mass (kg)	43.85±3.28	43.55±3.11	0.450	45.00±2.31	44.67±2.11	0.190	44.59±4.42	44.66±4.82	0.960	0.680
ES	0.150			0.260			0.000			

* p <0.05, p¹ Within-group statistical comparison (Wilcoxon test), p² Statistical significance value of comparison between groups (Kruskal Wallis Test), X: Average, SD: Standard Deviation, WBV: Whole Body Vibration, BMI: Body Mass Index, kg: Kilogram, m2: Square meter, cm: Centimeter, n: Number, %: Percentage, BT: Before Training, AT: After Training, ES: Effect Size.

Tablo 3. Comparison of the Findings on Flexibility Balance and Functional Strength of Core Muscle.

	Pilates Group (n=12) (X±SD)			WBV Group (n=12) (X±SD)			Control Group (n=12) (X±SD)			p²
	BT	AT	p¹	BT	AT	p¹	BT	AT	p¹	
Sit and Reach Test (cm)	-10.75 94.8±	3.08 90.2±	**0.001**	-5.08 60.4±	1.66 83.2±	**≤0.010***	-5.33 89.6±	-3.50 16.5±	0.194	**≤0.010***
ES	0.620			0.620			0.260			
Functional reach test (cm)	34.00 15.5±	44.08 08.3±	**≤0.010***	36.08 23.3±	44.91 12.5±	**≤0.010***	37.16 32.4±	41.16 37.5±	**≤0.010***	0.130
ES	0,620			0,620			0,580			
"Sit-ups" test (The number of repetitions)	5.25±3.16	10.75±2.63	**≤0.010***	8.08±4.85	12.08±2.93	**0.020***	8.66±3.93	9.41±3.17	0.260	0.110
ES	0.620			0.580			0.400			
Modified "push-ups" test (The number of repetitions)	1.75±2.70	8.66±2.05	**≤0.010***	3.66±3.49	8.25±2.00	**0.020***	6.58±4.87	7.08±4.46	0.430	0.390
ES	0.620			0.610			0.240			

*p<0.05, p¹ Intra-group statistical comparison (Wilcoxon test), p² statistical significance value of comparison between groups (Kruskal Wallis Test), X: Mean, SD: Standard Deviation, WBV: Whole Body Vibration, BT: Pre-Training, AT: Post-Training, n: Number, cm: Centimeters, ES: Effect Size.

group (p> 0.05). Analysis of body composition findings across the study groups similarly indicated no discernible distinctions (p> 0.05). In terms of effect size analysis per group: Body composition findings in the Pilates group exhibited effect sizes ranging between 0.07 and 0.24, characterized as low. In the WBV exercises group, waist-hip ratio and lean mass demonstrated low effect sizes, while muscle weight and fat percentage displayed moderate effect sizes, and BMI and fat weight manifested high effect sizes. Body composition findings are detailed in Table 2.

Comparisons of participants' flexibility values are provided in Table 3. A statistically significant difference in flexibility was evident among all three groups (p≤0.01). In intra-group comparisons, significant differences were identified in the Sit-Reach Test results before and after training in both Pilates and WBV exercises groups (p≤0.01). Conversely, no statistically significant discrepancy was observed in the Sit-Reach Test outcomes pre- and post-training within the control group (p>0.05). Considering effect size analysis: Pilates and WBV exercises groups exhibited high effect sizes.

The control group demonstrated low effect sizes. Pairwise comparisons of flexibility findings are detailed in Table 4. No statistically significant distinctions emerged between the Pilates and WBV groups in these paired comparisons (p>0.017). However, significant differences were noted between the Pilates and control groups, as well as between the WBV and control groups, in the Sit-Reach Test (p<0.017).

No statistically significant differences in balance were discerned across all three groups (p>0.05). In intra-group assessments, a significant discrepancy was apparent in all groups' balance scores before and after training (p<0.05). Effect size analysis revealed high effect sizes for balance outcomes within all three groups. Pairwise comparisons of balance findings where no statistically significant

Table 4. Comparisons of Individuals' Findings on Flexibility, Balance and Functional Strength of Core Muscle in Pairs.

	Pilates Group-WBV Group	Pilates Group-Control Group	WBV Group-Control Group
	p³	p³	p³
Sit and Reach Test (cm)	0.267	**≤0.010***	**0.010***
Functional reach test (cm)	0.930	0.110	0.050
"Sit-ups" test (THE number of repetitions)	0.130	0.430	0.050
Modified "push-ups" test (THE number of repetitions)	0.810	0.180	0.320

p³ Pair comparison (Mann-Whitney U Test), *p<0.017 (Bonferroni Correction), WBV: Whole Body Vibration, cm: Centimeters.

differences were observed in paired group comparisons (p>0.017). When the findings regarding the strength of the core muscles of the study participants were examined, no statistical difference was observed between the three groups in the sit-ups and modified push-ups tests in the pre- and post-training evaluations (p>0.05). In intra-group comparisons, there was a significant difference in the findings regarding the strength of the core muscles in the Pilates and WBV groups in the pre- and post-training evaluations (p <0.05); There was no significant difference in the findings regarding the strength of the core muscles in the control group (p>0.05).

DISCUSSION

In our investigation, an 8-week Pilates training demonstrated no noteworthy influence on body composition. Conversely, the application of WBV exhibited the capacity to decrease body fat weight and fat percentage. Notably, body composition remained relatively unchanged within the control group. Turning to the realm of flexibility, a substantial distinction was detected across all groups. Although both the Pilates and WBV groups displayed significant variations in comparison to the control group, no significant differentiation emerged between the Pilates and WBV groups. Evaluation of individuals' balance outcomes yielded no significant variations in terms of balance within all three groups. Intriguingly, significant differences were revealed in intragroup assessments for all groups both before and after training. When looking at the functional strength of the core muscles, in intra-group comparisons, there was a significant difference in the findings regarding the strength of the core muscles in the Pilates and WBV groups in the pre- and post-training evaluations.

Body composition stands as one of the vital health indicators, and excessive body weight and fat pose a common and substantial health concern. At the study's outset, the participants exhibited BMI values spanning from normal to overweight. Post-training, there were no BMI changes in the Pilates and control groups. Conversely, a reduction in BMI was observed in the WBV group. However, this decrease wasn't significant compared to the other groups. Initially, the waist-to-hip ratios of the subjects were within the normal range. Post-training, no alteration in waist-to-hip ratio was observed in any group.

Ideally, the recommended body fat ratio for women is around 25% (29). Initially, body fat ratios ranged from normal to risky levels. Upon analyzing the BEA (Body Electrical Analyzer) results, a minor decrease in muscle weight, fat percentage, and fat weight was noted in the WBV group. Nevertheless, this change wasn't statistically significant when compared to the pilates or control group. Based on these outcomes, the eight-week pilates exercise regimen did not yield significant effects on body composition. Although changes were observed in the WBV group, these changes did not exhibit superiority over the other groups.

Particularly, alterations in BMI values stemmed from both the modest increase in muscle mass and the notable reduction in fat mass. While a substantial body weight transformation was not anticipated in our study, shifts in muscle and fat ratios were expected.

Literature contains studies both supporting and refuting the effectiveness of pilates and WBV training on body composition. For instance, Jago et al. (30) conducted a study involving 30 young girls aged 11 years, where pilates training was administered five days a week for four weeks, demonstrating the effectiveness of pilates exercises in reducing BMI. However, we think that the fact that this study consists of 11-year-old teenage girls may affect the results of the study. Similarly, a study revealed positive effects of pilates training using the 'Reformer®' apparatus on body composition among healthy women (31). We also believe that the duration of this study being conducted over 16 weeks may have influenced the effect of pilates on body composition in long-term training. A systematic review on the effects of the pilates method has also reported that to change anthropometric variables and body composition, two to four sessions per week for eight weeks or longer are necessary (32). In investigations akin to our own, Şavkın and Aslan found that an eight-week pilates training regimen improved body composition values assessed via hip circumference measurements and BEA (23). A review published in 2015 on WBV highlighted its effectiveness on body composition (33). However, Segal et al., in their study involving 32 healthy adults, reported no changes in body composition assessed via BEA after administering pilates training (34,35) . Likewise, Rubio-Arias et al. noted that their three-day-a-week, six-week WBV training in healthy individuals did not impact body composition (35,36).

Zago et al. concluded that altering body composition in obese patients necessitated a minimum of 10 weeks of WBV training (37). On the other hand, Sekendiz et al. recommended a comprehensive approach involving proper training, sustained follow-up studies, and a well-balanced dietary program to effectively reduce weight and fat percentage (38).

Flexibility constitutes a vital component of physical fitness, often evaluated through various methods, with the Sit-Reach Test being the most common measurement. In our study, the Sit-Reach Test was utilized to assess flexibility. Initial values of the participants were notably low. Upon completion of the training, it became evident that both pilates and WBV led to a similar improvement in flexibility. This enhancement aligns with the anticipated outcome in accordance with the fundamental goals and principles of pilates exercises (39).

Meanwhile, the impact of WBV training on flexibility can be attributed to neural circulation and thermoregulatory factors. In stretching exercises, the pain threshold acts as a natural limit. Vibration application, however, elevates this threshold, allowing for more effective stretching. The application of WBV to muscles induces a significant analgesic effect during and post-application. Another possible mechanism involves muscle relaxation followed by the inhibition of contraction due to the excitation of the Golgi tendon organ (40,41). Abundant evidence supports the effectiveness of pilates and WBV on flexibility, which is congruent with the findings of our study.

Balance encompasses a multifaceted process involving sensory, motor, and cognitive elements. The central nervous system combines somatosensory, visual, and vestibular inputs to determine body position, posture, and motor responses. Skill in maintaining balance is pivotal during movement or static positions and significantly influences the development of other motor systems. Our study revealed an increase in balance across all three groups, with no discernible inter-group differences. The anticipated elevation in balance within the pilates and WBV groups aligns with expectations. However, the unanticipated enhancement in the control group's balance could be linked to a learning effect associated with the test.

Contradictory findings exist within the literature. Johnson et al., exploring the effects of "reformer" pilates training on balance in healthy adults, concluded that a 5-week, 2-days-a-week training regimen improved balance in 17 individuals (42). Kloubec's research, investigating the effects of 12-week, 2-days-a-week mat pilates training on muscular endurance, flexibility, balance, and posture in 50 healthy individuals, revealed enhanced muscle endurance and flexibility due to pilates exercises. While balance and posture improvements were not significant compared to the control group (43). Research exploring WBV's impact on balance generally involves elderly individuals and those with neurological conditions. Ebersbach et al. found that WBV application improved balance and gait but was not superior to conventional exercises (44).

In our literature review, we could not find any study evaluating the effect of WBV on the core muscles. The reason for this is that the strengthening effect of WBV is thought to be directly on the extremity muscles. In our study, although intra-group values in functional core strength were positively affected, it was observed that this increase was not different from the control group. Tolnai and colleagues found that 10 weeks of pilates training once a week in healthy young women was effective on endurance assessed by plank test and strength assessed by sit ups test (39).

The results of the study found that both pilates exercises and WBV training improved flexibility, balance, and functional strength of core muscles. Additionally, WBV training led to a decrease in BMI and BIA parameters. Based on the findings of this study, if an individual's primary goal includes reducing body composition, they should prefer WBV training. While pilates training improves flexibility, balance, and functional strength of core muscles, when performed alone, it does not significantly alter body composition parameters.

Our study had some limitations. The first limitation of our study is that single or double blindness could not be achieved. Another limitation was that individuals' daily work and activity factors were not controlled. At the beginning of the study, all individuals were asked not to participate in any other exercise or diet program. But occupational factors, housework and leisure activities were not limited. Pilates and WBV are trainings that involve the whole body. In terms of muscle strength, not only core functional strength but also lower and upper extremity strengths could be evaluated objectively.

As a result, it was found that Clinical pilates and WBV exercises trainings applied two days a week for eight weeks had the same positive effects on flexibility.

It was observed that both trainings can be used safely, except for simple side effects such as headache (in WBV) and delayed onset muscle soreness. Pilates and WBV exercises trainings are applied to both healthy and patient populations, and their use in clinics is becoming increasingly common. Different application methods or parameters have been used in studies in literature. For this reason, the results of the studies vary. However, there are very few studies comparing both training methods. We think that there is a need for research comparing pilates and WBV exercises training and that our study will guide other studies on this subject.

In accordance with the findings of our study, significant intragroup differences were identified within the WBV group concerning BMI, muscle weight, fat weight, and fat percentage. Conversely, in all other groups, no significant disparities were observed in terms of body composition data, and there was no discernible distinction between the three groups. Notably, significant differences emerged among all three groups concerning flexibility, while no statistically significant variation was detected in terms of balance within the groups. Intriguingly, intragroup comparisons yielded statistically significant differences for all groups both before and after training.

WBV and pilates training are applied across both healthy and patient populations, and their clinical application is on the rise. Variation in application methods and parameters among studies in the literature leads to differing outcomes. Consequently, there is a scarcity of studies comparing both training methods. We propose that further investigations comparing pilates and WBV training are warranted, and we believe our study will provide guidance for future research in this domain.

Sources of Support: The authors affirm no involvement of sponsors that could have potentially influenced the outcome of this study.

Conflicts of Interest: The authors declare no conflicts of interest with any financial organization pertaining to the content discussed in this manuscript.

Author Contributions: Busra KALKAN BALAK contributed to data collection, interpretation, and analysis. Zeliha Ozlem YURUK designed the study, led conceptualization, analysis, manuscript composition, and revision for approval. All authors have granted their approval for the final article.

Explanations: None.

Acknowledgments None.

REFERENCES

1. World Health Organization. Physical activity 25/07/2018 [Available from: http://www.who.int/mediacentre/factsheets/fs385/en/.
2. Guthold R, Stevens GA, Riley LM, Bull FCJTlgh. Worldwide trends in insufficient physical activity from 2001 to 2016: a pooled analysis of 358 population-based surveys with 1· 9 million participants. 2018;6(10):e1077-e86.
3. Güzel N. Fiziksel Aktivite, Egzersiz ve Spor, Hipokrat kitapevi; 2017.
4. Latey P. The Pilates method: history and philosophy. Journal of bodywork movement therapies. 2001;5(4):275-82.
5. Rittweger J. Vibration as an exercise modality: how it may work, and what its potential might be. European journal of applied physiology. 2010;108(5):877-904.
6. Alam MM, Khan AA, Farooq MJW. Effect of whole-body vibration on neuromuscular performance: A literature review. 2018;59(4):571-83.
7. de Oliveira LC, de Oliveira RG, de Almeida Pires-Oliveira DA. Effects of whole-body vibration versus pilates exercise on bone mineral density in postmenopausal women: a randomized and controlled clinical trial. Journal of Geriatric Physical Therapy. 2019;42(2):E23-E31.
8. Mobley-Meulman M. Exercise participation during weight loss on a high protein-low carbohydrate diet plan in females aged 15-25 years: East Tennessee State University; 2013.
9. Saglam M, Arikan H, Savci S, Inal-Ince D, Bosnak-Guclu M, Karabulut E, et al. International physical activity questionnaire: reliability and validity of the Turkish version. Perceptual motor

skills. 2010;111(1):278-84.

10. An H-Y, Chen W, Wang C-W, Yang H-F, Huang W-T, Fan S-YJIjoer, et al. The relationships between physical activity and life satisfaction and happiness among young, middle-aged, and older adults. 2020;17(13):4817.
11. Borga M, West J, Bell JD, Harvey NC, Romu T, Heymsfield SB, et al. Advanced body composition assessment: from body mass index to body composition profiling. 2018;66(5):1-9.
12. McLester CN, Dewitt AD, Rooks R, McLester JRJEJoSS. An investigation of the accuracy and reliability of body composition assessed with a handheld electrical impedance myography device. 2018;18(6):763-71.
13. Marini E, Campa F, Buffa R, Stagi S, Matias CN, Toselli S, et al. Phase angle and bioelectrical impedance vector analysis in the evaluation of body composition in athletes. 2020;39(2):447-54.
14. Witvrouw E, Mahieu N, Danneels L, McNair PJSm. Stretching and injury prevention: an obscure relationship. 2004;34:443-9.
15. Activity TJCSfE-cP, Health Canada O, Canada,. Fitness & Life-Style Approach (CPAFLA): CSEP-Health & Fitness Program's Health-Related Appraisal and Counselling Strategy. 2003.
16. Lemmink KA, Kemper HC, Greef MH, Rispens P, Stevens MJRqfe, sport. The validity of the sit-and-reach test and the modified sit-and-reach test in middle-aged to older men and women. 2003;74(3):331-6.
17. Heyward VHJM, Sports Si, Exercise. Advanced fitness assessment and exercise prescription. 2002;24(2):278.
18. Rosa MV, Perracini MR, Ricci NAJAoG, Geriatrics. Usefulness, assessment and normative data of the Functional Reach Test in older adults: a systematic review and meta-analysis. 2019;81:149-70.
19. Kamath T, Sandesh TJIJPESH. The test retest reliability and concurrent validity of functional reach test in 5 to 15 years old children with Down's syndrome-A cross sectional study. 2017;4:523-9.
20. Lesch KJ, Tuomisto S, Tikkanen HO, Venojärvi MJIjospt. Validity and reliability of dynamic and functional balance tests in people aged 19-54: a systematic review. 2024;19(4):381.
21. Baltacı G, Tunay VB, Tuncer A, Ergun N. Spor yaralanmalarında egzersiz tedavi: Hipokrat Kitabevi; 2016.
22. Ryman Augustsson S, Bersås E, Magnusson Thomas E, Sahlberg M, Augustsson J, Svantesson UJAiP. Gender differences and reliability of selected physical performance tests in young women and men. 2009;11(2):64-70.
23. Şavkin R, Aslan UB. The effect of Pilates exercise on body composition in sedentary overweight and obese women. The Journal of sports medicine physical fitness. 2016;57(11):1464-70.
24. Ecemiş ZB, Tor ÖB, Çobanoğlu G, Suner-keklik S, Kafa N, Güzel NAJTFvRD. Whole-body vibration effect on muscle activations:Which one is the most effective, low frequency or high frequency? 2024;35(1):66-72.
25. Perchthaler D, Horstmann T, Grau SJJoss, medicine. Variations in neuromuscular activity of thigh muscles during whole-body vibration in consideration of different biomechanical variables. 2013;12(3):439.
26. Machado A, García-López D, González-Gallego J, Garatachea N. Whole-body vibration training increases muscle strength and mass in older women: a randomized-controlled trial. Scandinavian journal of medicine science in sports. 2010;20(2):200-7.
27. Corder GW, Foreman DI. Nonparametric statistics for non-statisticians. John Wiley Sons, Inc.; 2011.
28. Cohen J. Statistical power analysis for the behavioral sciences: Routledge; 2013.
29. Rask-Andersen M, Karlsson T, Ek WE, Johansson ÅJNc. Genome-wide association study of body fat distribution identifies adiposity loci and sex-specific genetic effects. 2019;10(1):339.
30. Jago R, Jonker ML, Missaghian M, Baranowski T. Effect of 4 weeks of Pilates on the body composition of young girls. Preventive medicine. 2006;42(3):177-80.
31. Vaquero-Cristóbal R, Alacid F, Esparza-Ros F, López-Plaza D, Muyor JM, López-Miñarro PA. The effects of a reformer Pilates program on body composition and morphological characteristics in active women after a detraining period. Women Health. 2016;56(7):784-806.
32. Vaquero-Cristóbal R, Alacid F, Esparza-Ros F, Muyor JM, López-Miñarro PAJAMdlE. Pilates: efecto sobre la composición corporal y las variables antropométricas. 2014;49(183):85-91.
33. Park S-Y, Son W-M, Kwon O-S. Effects of whole body vibration training on body composition, skeletal muscle strength, and cardiovascular health. Journal of exercise rehabilitation. 2015;11(6):289.
34. Bullo V, Bergamin M, Gobbo S, Sieverdes J, Zaccaria M, Neunhaeuserer D, et al. The effects of Pilates exercise training on physical fitness and wellbeing in the elderly: A systematic review for future exercise prescription. 2015;75:1-11.
35. Duyan M, Ilkim M, Çelik TJPJoM, Sciences H. The Effect of Social Appearance Anxiety on Psychological Well-Being: A Study on Women Doing Regular Pilates Activities. 2022;16(02):797-797.
36. Rubio-Arias J, Esteban P, Martínez F, Ramos-Campo D, Mendizábal S, Berdejo-Del-Fresno D, et al. Effect of 6 weeks of whole body vibration training on total and segmental body composition in healthy young adults. Acta Physiologica Hungarica. 2015;102(4):442-50.
37. Zago M, Capodaglio P, Ferrario C, Tarabini M, Galli M. Whole-body vibration training in obese subjects: a systematic review. PloS one. 2018;13(9):e0202866.
38. Alizadeh S, Daneshjoo A, Zahiri A, Anvar SH, Goudini R, Hicks JP, et al. Resistance training induces improvements in range of motion: A Systematic Review and Meta-analysis. 2023;53(3):707-22.
39. Tolnai N, Szabó Z, Köteles F, Szabo A. Physical and psychological benefits of once-a-week Pilates exercises in young sedentary women: A 10-week longitudinal study. Physiology behavior. 2016;163:211-8.
40. Gerodimos V, Zafeiridis A, Karatrantou K, Vasilopoulou T, Chanou K, Pispirikou EJJos, et al. The acute effects of different whole-body vibration amplitudes and frequencies on flexibility and vertical jumping performance. 2010;13(4):438-43.
41. Siegmund LA, Barkley JE, Knapp D, Peer KSJAT, Care SH. Acute effects of local vibration with biomechanical muscle stimulation on low-back flexibility and perceived stiffness. 2014;6(1):37-45.
42. Johnson EG, Larsen A, Ozawa H, Wilson CA, Kennedy KLJJob, therapies m. The effects of Pilates-based exercise on dynamic balance in healthy adults. 2007;11(3):238-42.
43. Kloubec JAJTJoS, Research C. Pilates for improvement of muscle endurance, flexibility, balance, and posture. 2010;24(3):661-7.
44. Ebersbach G, Edler D, Kaufhold O, Wissel JJAopm, rehabilitation. Whole body vibration versus conventional physiotherapy to improve balance and gait in Parkinson's disease. 2008;89(3):399-403.