Süleyman Demirel Üniversitesi
Sağlık Bilimleri Dergisi
Cilt 13, Sayı 3, 497 - 509, 2022

Suleyman Demirel University
Journal of Health Sciences
Volume 13, Issue 3, 497 - 509, 2022

Sağlıklı Gençlerde Kısa Dönem Tüm Vücut Vibrasyon Egzersizinin Esneklik, Endurans ve Dinamik Denge Üzerine Etkisinin İncelenmesi: Randomize Kontrollü Çalışma

Examination of the Effect of Short-term Whole Body Vibration Training on Flexibility, Endurance and Dynamic Balance In Healthy Young People: A Randomized Controlled Study

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ABSTRACT

Objective: To investigate the effect of short-term (3 weeks) whole body vibration training (WBVT) in healthy young people.

Materials and Methods: Seventy six healthy individuals (mean age=22.55±1.22 years, 41 females and 35 males) were included in the study. Participants were randomly divided into two groups as WBVT group (n = 41) and control group (n =35). WBVT, consisting of 14 exercises for the trunk and lower extremities, was applied to the WBVT group 3 times a week for 3 weeks. The control group did not receive any training. Flexibility, lower extremity endurance, trunk endurance and dynamic balance respectively; measured with sit and reach test, sit and stand test, Biering Sorensen tests, lateral bridge and shuttle, Y balance test. All measurements were made at baseline and at the end of the 3rd week.

Results: After 3 weeks, in WBVT group, curl up test (p=0.023), chair stand test (p=0.015) and Y balance test were perfomed on right anterior (p=0.003), right posteromedial (p=0.001), right posterolateral (p=0.001), left anterior (p=0.001), left posterolateral (p=0.000), and left posteromedial (p=0.000) aspects were significant. In the control group, the results in the right anterior (p=0.019) and left anterior (p=0.025) aspects of the Y balance test were significant. When the delta values were compared, the difference in the right (p=0.018) and left (p=0.006) posterolateral directions of the Y balance test; it was significant in favor of the WBVT group.

Conclusion: It was observed that short-term whole body vibration training had positive effects on trunk flexor endurance and dynamic balance in healthy young people. New insights into the use of musculoskeletal rehabilitation and sports training programs can be provided by WBVT. Further studies are needed to examine the effectiveness of whole-body vibration training by comparing different loads, volumes and types.

Anahtar Kelimeler: Vibration, Postural balance, Exercise training

Alınış / Received: 14.02.2022 Kabul / Accepted: 29.11.2022 Online Yayınlanma / Published Online: 20.12.2022

DOI: 10.22312/sdusbed.1072810
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ÖZET

Amaç: Sağlıklı gençlerde kısa süreli (3 hafta) tüm vücut vibrasyon eğitiminin (TVVE) etkisini incelemektir.

Gereç ve Yöntem: Çalışmaya, 76 sağlıklı birey (yaş ort=22,55± 1,22 yıl, 41 kadın 35 erkek) dahil edildi. Katılımcılar randomize olarak iki gruba ayrıldı (TVVE grubu n = 41 ve kontrol grubu n =35). Gövde ve alt ekstremiteye yönelik 14 egzersizden oluşan tüm vücut vibrasyon eğitimi, haftada 3 kez, 3 hafta boyunca TVVE grubuna uygulandı. Kontrol grubuna, herhangi bir eğitim uygulanmadı. Esneklik, alt ekstremite enduransı, gövde enduransı ve dinamik denge sırasıyla; otur uzan testi, otur kalk testi, Biering Sorensen testleri, lateral köprü ve mekik, Y denge testi ile ölçüldü. Tüm ölçümler, başlangıçta ve 3. haftanın sonunda yapıldı.

Bulgular: 3 hafta sonra, TVVE grubunda mekik testi (p=0,023), otur kalk testi (p=0,015) ve Y denge testinin sağ anterior (p=0,003), sağ posteromedial (p=0,001), sağ posterolateral (p=0,001), sol anterior (p=0,001), sol posterolateral (p=0,000) ve sol posteromedial (p=0,000) yönlerindeki sonuçları anlamlı iken; kontrol grubunda ise Y denge testinin sağ anterior (p=0,019) ve sol anterior (p=0,025) yönlerindeki sonuçlar anlamlı idi. Delta değerleri karşılaştırıldığında, Y denge testinin sağ (p=0,018) ve sol (p=0,006) posterolateral yönlerindeki fark; TVVE grubu lehine anlamlı idi.

Sonuç: Kısa süreli tüm vücut vibrasyon eğitiminin, sağlıklı gençlerde gövdenin fleksör yöndeki enduransı ve dinamik denge üzerine olumlu etkilerinin olduğu görüldü. TVVE ile kas-iskelet rehabilitasyonu ve spor eğitim programlarının kullanımına ilişkin yeni bilgiler sağlanabilir. Farklı yükleri, hacimleri ve türleri karşılaştırarak tüm vücut vibrasyon eğitiminin etkinliğini inceleyen daha fazla çalışmaya ihtiyaç vardır.

Keywords: Vibrasyon, Postüral denge, Egzersiz eğitimi

1. Introduction

Whole body vibration training (WBVT) is a new biophysical method that provides systemic vibration signals with mechanical stimuli. For many years it has been advocated that low amplitude, low frequency vibration does not harm the human body and is an effective approach to increase muscle strength [1].

WBVT was first administered on astronauts to reduce muscle atrophy and loss of bone mass due to the lack of gravitational force in space. Recently, it has become a popular method to improve health with clinical use extended from athletes to rehabilitation [2].

The stimulating effect of vibration on muscle tone has been demonstrated during the administration of WBVT. Mechanical vibrations stimulate sensory receptors in the tendons and skin, and more importantly, in the muscle spindles. Activation of muscle spindles reveals a stimulating effect in alpha motor neurons that cause muscle contraction [3]. A myostatic tension reflex, called ‘‘Tonic Vibration Reflex’’, occurs in monosynaptic (1a-afferents) and polysynaptic (II-afferents) pathways in muscle activity. With the application of vibration, the muscle starts to contract within a few seconds and the muscle contractions continue to increase until the end of the application. It has also been discussed that vibrational excitations enable the use of motor units that not normally used, in addition to this effect, increase neurotransmitter release via mechanosensors (primary afferents in muscle fibrils), thereby facilitating neuromuscular transmission [4].

WBVT also improves the complex interaction of postural control and agonist-antogonist muscles. Rees SS et al., in which WBVT was applied 3 times a week for 8 weeks, lower extremity muscle strength and postural balance were reported to increase [5]. WBVT stimulates proprioceptive pathways and increases positive feedback by creating wide sensory stimulation. Thus, this cycle can be used more effectively. As a result, isometric power increases. This mechanism shows that WBVT increases proprioception [6].

Although many studies in the literature indicate that WBVT interventions provide increased lower extremity muscle strength [7-9], to our knowledge, only one study investigated the effect of an 8-week WBVT on trunk muscle strength and dynamic balance, and the results were found to be positive. [7]. Muscle strength increases with the first week of training [8]. However, in the literature, there is a general information that at least 8 weeks of force training should be completed to be able to observe hypertrophic changes in muscle [11]. The lack of time is the most common reason for abandoning treatment programs [12,13]. Therefore, we planned to conduct this study within 3 weeks.

The aim of the study was to investigate short-term effects (3 weeks) of WBVT on muscular endurance, dynamic balance and flexibility in healthy young individuals.

2. Material and Method

Ethical approval of the study was obtained from XXX University local ethics committee at the board meeting dated 05.03.2019 and numbered 05. All procedures were undertaken in compliance with the Declaration of Helsinki. All individuals were informed verbally and informed consent forms were signed. This study was planned with randomized controlled parallel groups to evaluate adaptations after WBVT through comparisons with the control group. Training and evaluations before and after the treatment were done by different physiotherapists.The physiotherapist performing the evaluations was blinded to the two groups.

Participants

As a result of the power analysis, it was calculated that 80% power could be obtained with 95% confidence when at least 42 subjects (at least 21 per group) were included in the study. A total of 82 volunteers who met the inclusion criteria of the study were randomly separated into two groups as the WBVT group (n=41) and the control group (n=41). Six participants from the control group were excluded from the study because their final assessment could not be made. Thus the study was completed with a total of 76 participants, 41 in the WBVT group and 35 in the control group. The flowchart of the study design is shown in Figure 1.

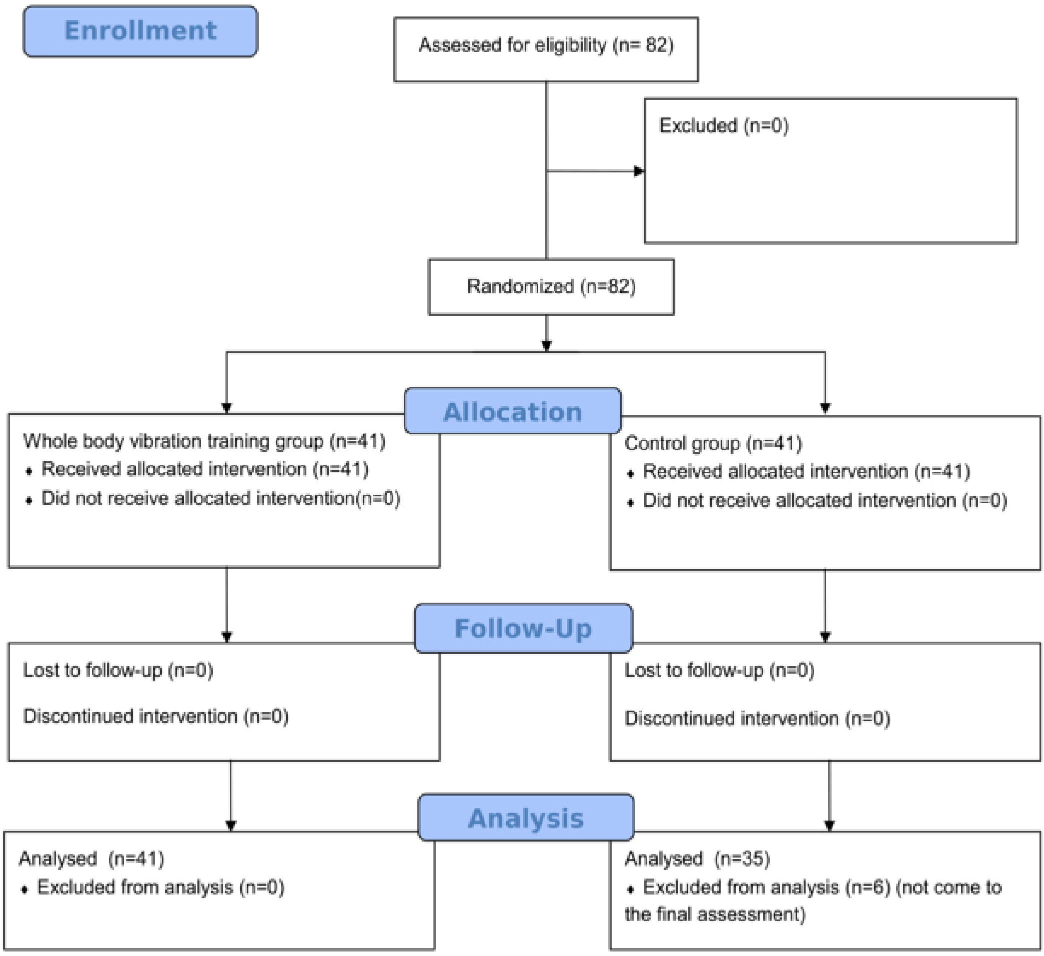


Figure 1: Flowchart of progress through the phases of the study

Inclusion criteria were voluntary participation and in the 20-30 age range.

Exclusion criteria were as follows: (a) regularly performing aerobic and strength training at least 3 days a week for the past three months. (b) the presence of, pulmonary, cardiovascular, neurological or orthopedic problems that may interfere with exercise. (c) any lower extremity surgery, history of severe trauma or fracture (d) diabetes, neuropathies, balance disorders and other conditions affect balance. (e) to have previously received WBVT training. (f) taking any medication that could affect neuromuscular performance during the previous two weeks. (g) failure to attend at least 75% of the program. Data from any participant showing symptoms and signs of injury, such as swelling, loss of function or pain, before or during data collection, were not included in the study, the participation of that individual was discontinued.

Evaluation

All assessments were performed at the beginning and at the end of the third week by the same experienced physiotherapist according to standard test protocols and under the same conditions. Before starting the tests, participants were allowed to adapt by the same therapist. Flexibility was assessed with the sit-and-reach test, trunk endurance was assessed with curl up, lateral bridge and Biering Sorensen tests, lower extremity endurance was assessed with the chair stand test and dynamic balance was assessed with the Y balance test. Instead of instrumental tests (such as isokinetic dynamometer) for evaluation, we chose to use functional tests because they involve activities of daily living.

Sit and Reach Test: The standard sized sit and reach test table was placed in full contact with the participant's bare soles of feet. The patients were asked to extend forward with their trunk without disturbing the full extension of their arms, fingers and knees. A value of >100 cm means that the participant can extend further than the toes (good flexibility), a value of <100 cm indicated that participant could not reach the toes (poor flexibility). The average of three trials was recorded [14].

Curl Up Test: The participant, who was in the supine hooked position on the mat with hands clamped on the neck was instructd to raise the trunk until the scapula was off the ground. The number of repetitions in 30 seconds was recorded [15].

Lateral Bridge Test: The participant lying on the non-dominant side was asked to form a support surface from the lower arm and elbow, to place the other hand on the waist and to bridge the hip and knee. The time of maintained balance, was recorded [16].

Biering Sorensen Test: The participant lay prone on the bed with the body suspended from the anterior superior of the spina iliaca, fixed at the level of the gastrocnemius muscle. The patient was instructed to hold the body parallel to the ground by clamping their hands on the chest and the time of maintaining this parallel position was recorded [17].

Chair Stand Test: The participant, sitting on a standard 43 cm high chair with her/his arms crossed at the shoulders, was asked to stand up and sit quickly for 30 seconds, and the number of repetitions at which the full take-off occurred was recorded [18].

Y balance test: Starting on the right foot, the ubject was instructed to place the other foot with the toes pointing in three directions (anterior, postero-medial and posterolateral) while standing on one foot. Care was taken to maintain balance by placing the heel of the foot on the ground, and lightly extending the toes then bringing that foot to the standing foot without touching the ground. The test was repeated 3 times with 15 seconds rest intervals for each direction and the best score was recorded in cm [19].

Intervention

The WBVT was performed with Compex® Winplate (Germany). The training was conducted 3 times a week for 3 weeks and in each session, all 14 exercises were performed with one repetition. Rest intervals were given for at least 1 day between treatment sessions. The treatment sessions lasted approximately 30 minutes. Before starting the study, the participants were explained and shown the exercises in detail. The participants were told that they could leave the study at any time.

In Figure 2, the 14 exercises for the lower extremity and trunk, which were performed in a single session of the WBVT, are shown. The exercises included both extremities. Figure 3 shows the details of the WBVT program. Participants in the WBVT group stood barefoot, sat, or placed their foot or knee on a vibration platform. They were told to hold onto the handlebars for standing exercises. The training was carried out under the supervision of a physiotherapist. During the exercise, joint angles were measured with a goniometer to standardize the positions. In order to increase the effectiveness of the training, the frequency and duration of application were increased and the rest period was shortened as the weeks progressed. Training related injuries related were not reported. The rate of participation in the treatment sessions was 95%.

The participants in the control group were instructed to continue their daily activities and no training was given. Each week, telephone calls were made to check if they had started any exercise.

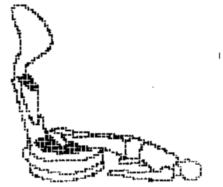
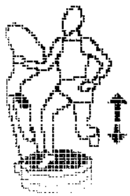
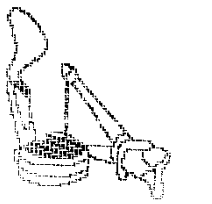
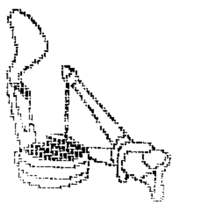
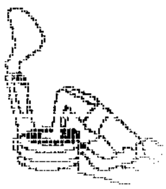
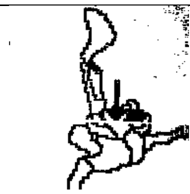
1st exercise		8th exercise	
2nd exercise		9th exercise (right)	
3rd exercise		10th exercise (left)	
4th exercise (right)		11th exercise (right)	
5th exercise (left)		12th exercise (left)	
6th exercise		13th exercise (right)	
7th exercise		14th exercise (left)	

Figure 2. Fourteen exercises performed in a single session of the WBVT

Table 1: The details of the whole body vibration training program

	Level I (first week)			Level II (second week)			Level III (third week)		
	Frequency (Hz)	Active (sec)	Rest (sec)	Frequency (Hz)	Active (sec)	Rest (sec)	Frequency (Hz)	Active (sec)	Rest (sec)
1 st exercise	30	30	30	30	40	30	35	40	25
2 th exercise	35	30	30	35	40	30	40	40	25
3 rd exercise	35	40	30	35	50	30	40	40	25
4 th exercise	35	30	30	35	40	30	35	40	25
5 th exercise	35	30	30	35	40	30	40	50	25
6 th exercise	30	30	30	30	35	30	40	40	25
7 th exercise	30	30	30	30	35	30	40	40	25
8 th exercise	35	40	30	35	40	30	35	35	25
9 th exercise	35	30	30	35	35	30	35	35	30
10 th exercise	35	30	30	35	35	30	35	35	25
11 th exercise	30	30	30	35	35	30	35	35	25
12 th exercise	30	30	30	35	35	30	40	40	25
13 th exercise	30	30	30	35	35	30	40	35	25
14 th exercise	30	30	30	30	35	30	40	35	25

Statistical analysis

Data were analyzed with SPSS 21.0 version package program. To determine whether continuous variables showed normal distribution, Kolmogorov-Smirnov Test was used. Paired sample t –test was used within groups and Independent t – test was used between groups, if the data distribution is normal. Wilcoxon signed rank test was used within groups and Mann Whitney U test was used between groups if the data is not normal. Continuous variables were given as mean ± standard deviation, and categorical variables as numbers and percentages. Mann Whitney U test was used to analyze the demographic data of the groups and Wilcoxon test to analyze the data obtained at the beginning and at the end of the 3rd week. P value of <0.05 was considered statistically significant.

3. Results

The study included 76 healthy volunteers aged 20-30 years (41 females, 35 males, age: 22.55±1.22 years, BMI: 22.06±3.11 kg/m^2). The WBVT group consisted of 41 participants (26 females, 15 males, age = 22.58±1.11 years, BMI = 21.96±3.12 kg/m^2) and the control group consisted of 35 participants (19 females, 16 males, age = 22.51±1.35 year, BMI = 22.18±3.14 kg/m^2).

The demographic data of the participants before the evaluations is shown in Table 1. There was no statistical difference between the demographic data of the groups (p>0.05).

Table 2: Demographic characteristics of the patients

Variables	WBVT Group (n=41) M±SD	Control Group (n=35) M±SD	p
Age (years)	22.58±1.11	22.51±1.35	0.961*
Body weight (kg)	63.97±13.71	66.31±14.64	0.514*
Height (m)	1.69±0.09	1.72±0.08	0.353*
BMI (kg/m^2)	21.96±3.12	22.18±3.14	0.731*
Gender (female/male) (n)	26/15	19/16	0.420**

M=mean, SD=standard deviation, WBVT= Whole body vibration training, * Mann Whitney U test, **Chi-Square Test

When comparing the data at the beginning and end of the 3rd week, in the WBVT group; the difference in curl up (p=0.023), chair stand (p=0.015), right anterior (p=0.003), right posteromedial (p=0.001), right posterolateral (p=0.001), left anterior (p=0.001), left posterolateral (p=0.000), and left posteromedial (p=0,000) reach of Y balance test was significant, the difference in Biering Sorensen (p=0.693), sit and reach (p=0.539) and lateral bridge (p=0.120) test was not significant (p=0.671). In the control group, the difference in right anterior (p=0.019) and left anterior reach (p=0.025) of Y balance test was significant and no significant difference was found in all other tests (p>0.05) (Table 2).

The Delta values of the participants were calculated by subtracting the pre-treatment result from the post-treatment result. When the delta values were compared, difference was significant in right (p=0.018) and left (p=0.006) posterolateral dynamic balance in favor of WBVT group (Table 3).

Table 3: The comparison of baseline and the end of the 3rd week results of groups

Variables	WBVT Group (n=41)			Control Group (n=35)		
	Baseline	End of 3 weeks	p*	Baseline	End of 3 weeks	p*
	M±SD	M±SD		M±SD	M±SD	
Sit-And-Reach Test (cm)	99.65±11.32	100.02±10.84	0.539	99.25±11.65	99.75±11.35	0.321
Curl Up Test (repetition)	14.87±4.49	16.09±5.41	**0.023**	14.05±4.19	14.57±4.46	0.253
Side Bridge Test (sec)	39.05±21.18	42.34±23.16	0.120	34.29±20.35	35.81±17.97	0.325
Biering Sorensen Test (sec)	81.49±33.24	83.08±36.20	0.693	70.60±37.16	71.36±37.42	0.707
Chair Stand Test (repetition)	17.75±4.07	18.80±4.51	**0.015**	16.82±4.12	17.48±4.75	0.132
Y Balance Test (cm)						
Right-anterior	65.02±6.89	67.31±6.46	**0.003**	71.09±9.33	73.78±8.12	**0.019**
-posteromedial	99.15±13.18	102.56±12.43	**0.001**	101.45±12.11	104.01±10.39	0.072
-posterolateral	98.20±12.65	101.69±11.34	**0.001**	102.22±13.78	102.07±13.14	0.963
Left -anterior	65.37±7.98	68.01±7.08	**0.001**	71.14±10.04	73.91±6.54	**0.025**
-posteromedial	98.99±12.82	102.35±11.96	**0.000**	101.48±11.75	103.21±10.47	0.116
-posterolateral	97.28±12.37	101.12±12.04	**0.000**	100.42±13.87	101.58±13.65	0.421

Significant values are shown in bold
M=mean, SD=standarddeviation, WBVT= Whole body vibration training, *WilcoxonTest

Table 4: The comparison of delta values with groups

Variables	WBVT Group (n=41)	Control Group (n=35)	p
	Δ M±SD	Δ M±SD	
Sit-And-Reach Test (cm)	0.36±3.94	0.50±3.67	0.777**
Curl Up Test (repetition)	1.21±2.96	0.51±2.63	0.402**
Side Bridge Test (sec)	3.29±13.23	1.51±12.05	0.495**
Biering Sorensen Test (sec)	1.59±23.90	0.76±17.12	0.770**
Chair Stand Test (repetition)	1.04±2.58	0.65±2.53	0.509*
Y Balance Test (cm)			
Right -anterior	2.29±4.60	2.68±5.66	0.942**
-posteromedial	3.40±6.78	2.55±7.01	0.184**
-posterolateral	3.49±6.05	-0.15±7.13	**0.010****
Left -anterior	2.63±4.75	2.77±6.58	0.914*
-posteromedial	3.35±4.36	1.72±7.05	0.240*
-posterolateral	3.84±5.96	1.16±8.23	**0.104***

Significant values are shown in bold
M=mean, SD=standard deviation, WBVT=Whole body vibration training, Δ=Posttreatment-pretreatment.
* Independent Samples Test, ** Mann-Whitney U Test.

4. Discussion and Conclusion

The aim of this study was to investigate the effects of short-term (3 weeks) WBVT on flexibility, muscular endurance and dynamic balance in healthy young individuals. The results showed that WBVT had an effect on trunk flexor endurance, lower extremity muscle strength and dynamic balance.

In this study, the flexibility changes of the subjects were evaluated by sit and reach test. When we examined the flexibility scores of the WBVT group and control group, the difference between the pre and post-treatment scores of the WBVT and the control group was not found to be statistically significant. The WBVT group scores increased between the pre and post-treatment results in terms of the flexibility values. There were no changes in the control and post-treatment scores. According to the literature, there are findings showing that acute WBVT might increase flexibility [20,21].

Although many studies in the literature have indicated WBVT interventions provide increased lower extremity muscle strength, to the best of our knowledge, only one study has focused on trunk muscle strength [7-9].

In studies investigating EMG signal response, rectus abdominus muscle activity during WBVT, leg muscle activities were obtained more and with significant activation at high frequency (15 Hz, maximum of 40 Hz, respectively) [22,23]. In the current study, in which high frequency (30 35 Hz) was used, according to the curl up and chair stand test results, an increase in abdominal and lower extremity muscle strength was obtained. Muscles often need more energy to maintain balance on unstable ground [24]. The increase in strength in these muscle groups can be considered to be the result of the need to meet this energy deficiency.

In addition, OxyHb concentrations of the motor, prefrontal, and somatosensory cortex areas, were shown to be higher at higher frequencies (27 Hz) in the study by Choi DS et al. [25]. Increased concentration of OxyHb results in arteriolar vasodilation in that area and increases blood flow [26]. Maikala et al. reported that a high frequency (27 Hz) of WBVT increased cerebral oxygenation responses in the prefrontal cortex [27]. Cerebral oxygenation and an increase in blood flow are closely associated with greater neural activation [26]. In the light of this information, the results obtained from the current study using high frequency can be considered to have been caused not only by changes in the motor unit, but also by adaptations at a high cortical level contributing to this development.

In the literature related to this subject, it has been emphasized that by enhancing alpha motor neuron activation with WBVT training, a significant improvement can be achieved in coordination and proprioception, and consequently increased postural control [28].

Muscle strength is defined as an important component in the development of proximal stabilization in dynamic trunk activity [29]. Improvements in strength are not only achieved by an increase in muscle mass, but neural adaptation is one of the main components of early development of strength [30]. The increase in the extension directions of the Y balance test may be the likely result of progression in postural control due to the development of neural adaptation in parallel with the increase in trunk strength. In addition, this relationship with lower extremity muscle strength has been shown in previous studies [31,32].

When the literature is examined related to healthy individuals, Schlee G et al. [11] reported that a single session of WBVT treatment had positive effects on static balance and Maeda N et al. [9] reported that WBVT applied for 8 weeks had positive effects on dynamic balance. In line with the literature, Y balance test results of our study showed that WBVT could improve dynamic balance. Dynamic balance plays an important role in providing daily living activities for example; running, climbing stairs and walking is an important element in demonstrating complex movement skills. Stability control is dynamic when a person is on the move. Therefore, dynamic balance has a more complex mechanism than static balance [33].

When the studies to date are examined, to the best of our knowledge, there is only one study focusing on the long-term effects of WBVT on trunk muscle and dynamic balance. This is a study conducted by Maeda et al. [9] on WBVT with a vibration frequency of 30 Hz applied to recreationally active, healthy, young males 3 days a week for 8 weeks. As a result of this study, a difference was determined in the flexor muscles of the trunk muscles and only in anterior extension of the Y balance test. In the current study, improvements were determined in both trunk flexor muscle strength and all extensions of the Y balance test in 3 weeks. Also, the delta values WBVT were showed improvement in both right and left posterolateral dynamic balance. It is important that WBVT makes this difference in a short period of three weeks. Similarly, in both studies, there was no improvement in muscle groups other than flexor muscles of the trunk. This suggests that this training method requires additional methods for the development of trunk extensor and lateral muscle strength.

It is an important result of the current study that trunk flexor muscle strength and dynamic balance were achieved in the short period of 3 weeks, rather than 8 weeks. This difference in a shorter time can be attributed to the gradual increase in the vibration frequency in this study and to the sedentary nature of the sample group, because it is thought that the performance changes usually caused by WBVT are mainly dependent on the vibration model and the duration of the intervention [34].

The strong aspect of this study were that the results of WBVT were compared with a control group, power analysis was applied when forming the sample, the sample size was sufficient and the age range was narrow.

A limitation of the study is that the results can only be generalized to healthy young adults and the experimental results do not fully reflect the situation of healthy individuals at different ages. A second limitation was the lack of monitoring of the duration of maintaining the effectiveness of WBVT.

As a result of this study, short-term WBVT was seen to have increased trunk flexor muscle strength and dynamic balance. However, short-term WBVT did not improve the extensor and lateral muscle strength of the trunk. In order to maintain lumbar health in healthy individuals and for more independent mobility of individuals in daily life, extensor and lateral muscle groups should be strong in addition to flexor muscle strength for stabilization of the trunk [35]. Therefore, it can be recommended that additional exercises can be planned for the development of the trunk extensor and flexor muscles of individuals receiving WBVT. New insights into the use of musculoskeletal rehabilitation and sports training programs can be provided by WBVT.

In further studies, there is a need for studies in which short-term efficacy is examined by comparing different load, volume and types of whole body vibration training in controlled studies.

Declaration of Ethical Code

In this study, we undertake that all the rules required to be followed within the scope of the "Higher Education Institutions Scientific Research and Publication Ethics Directive" are complied with, and that none of the actions stated under the heading "Actions Against Scientific Research and Publication Ethics" are not carried out.

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