Original Article

Effects of two different muscle strength training technique on balance and performance in healthy young people

Filiz ALTUĞ, Tuba CAN AKMAN, Nihal BÜKER, Uğur CAVLAK

Pamukkale University, School of Physical Therapy and Rehabilitation, Denizli, Turkey

Objective: To determine the effect of lower extremity muscle strength training in healthy young adults on improvement of stability and performance.

Methodology: In this study, 37 volunteers with mean age of 21.35±0.94 years were included and were randomly divided into 3 groups. Each group was trained for 3 days a week for 4 weeks. First group (group I) was trained with Russian stimulation to the knee extensors muscles, second group (group II) was trained by whole-body vibration (WBV) and third group (group III) was a control group and had no training. Balance was assessed with Portable Kinesthetic Ability Trainer (SPORTKAT 550). Quadriceps muscle strength was evaluated with Hand-Held dynamometer and lower extremity performance was measured with step-up test.

Results: Muscle strength (p>0.05), step-up test (p<0.05) and static balance increased (p<0.05) in group I and group II muscle strength (p>0.05) and step-up test (p<0.05) increase, while the decrease in static balance (p<0.05) was found. In III group, muscle strength (p<0.05) and static balance (p<0.05) increased, step up to the test (p> 0.05) decreased. After training muscle strength, static balance, and step up test results of participants in group I and II did not increase significantly compared to group III.

Conclusion: Although 4 weeks Russian stimulation and WBV methods improved the muscle strength in groups I and II compared to Group III, lower extremity endurance and the balance, there was no advantage relative to each other. (Rawal Med J 201;40: 137-144).

Keywords: Whole-body vibration, Russian stimulation, balance, performance.

INTRODUCTION

Balance is defined as the ability to maintain the projection of the body's center of mass within limits of the base of support, as in standing or sitting, or in transit to a new base of support, as in walking (1). Balance control is complex and multifactorial process; it depends on a well-functioning postural control system. This complex feedback system is based on the central processing of visual, vestibular, and somatosensory inputs on the afferent side and corresponding purposeful neuromuscular action on the efferent side.[1,2] The centers of gravity to make quick adjustments are required fast and strong muscle contractions.[3] Johnston et al. have shown that decreased lower extremity muscle strength effected the ability of faster walking, climbing the stairs and raising from a chair.[4]

Balance can be categorized by either static or dynamic balance. Static balance is the ability to sustain the body in static equilibrium or within its base of support. Dynamic balance is believed to be more challenging because it requires the ability to maintain equilibrium during a transition from a dynamic to a static state.[5] Carter et al. have identified that knee extension strength is a significant determinant of performance on static and dynamic balance tests in woman with osteoporosis.[6] There are many methods for evaluation of balance although none of them is accepted as the gold standard. Balance tests must be quick, reliable and measurable. Postural control is provided as a result of the coordinated work of the musculoskeletal system. Improving the bodies balance, especially maintained by the muscle of ankle, knee and hip joints are very important.[7] The aim of this study was to determine the effect of lower extremity muscle strength training on balance and lower extremity muscle performance in healthy young adults.

METHODOLOGY

Participants

In this study is a randomized controlled trial, participants gave informed consent and the study was conducted in accordance with the principles of

Helsinki Declaration. The study was approved by the Ethical Committee of Pamukkale University Medical Faculty. Volunteers with age 18 to 25 year without any neurological, orthopedics, musculoskeletal or other chronic diseases or visual or auditory problems were enrolled. Those with inability to complete the tests and training program were excluded from the study. Power analysis revealed that a sample size of 15 volunteer in each group was necessary to achieve a power of 0.80. Thus, 45 healthy volunteers were included and were randomly assigned to 3 groups.

Group I: Received electrical stimulation with Russian current (n=13). 2 healthy volunteers did not come to the training program. **Group II:** Received WBV training (n=12). 3 healthy volunteers did not come to the training program. **Group III:** Controls groups (n=12). 3 healthy volunteers did not come to the training program. The control group did not participate in any training program, and these subjects were instructed not to change their lifestyle.

The training programs were consisted of 12 training sessions over a 4-week period. Training frequency was three times a week, with at least 1 day of rest between sessions.

Training methods

Russian Stimulation: Electrical stimulation was given by non-invasive method to the Quadriceps Femoris muscle in both legs without voluntary effort associated with Russian current (2500Hz). The current was increased to provide technical contraction (10 repetitions of 10s contraction with 50s rest periods in between) for three days per week for four weeks.[8]

Whole Body Vibration: This was performed one a Compex-Winplate (ref: 360043009- Germany). The participants stood on the machine and positioned their feet around the centre of the oscillating platform. WBV training frequency were 30 Hz and 2,5 mm amplitude during each of five 1-minute periods. Each training session lasted 5 min. Training frequency was three times a week, for four weeks.[9]

Outcome Measurements

Subjects were assessed before and after the training by a blinded physiotherapist assigned to the study. Participants were given a 5-minute rest between each assessment.

Assessment of Balance Ability

Balance indices were recorded with Portable Kinesthetic Ability Trainer (SPORTKAT 550).

Two different protocols were used; static and dynamic.[10]

Assessment of Muscle Strength

A hand-held dynamometer was used to test bilateral maximum knee extensor muscle performance, and the right and left limb was tested by the same physical therapist. Three warm-up contractions were performed, with subjects instructed to gradually increase their knee extension force over 3 seconds. Three maximal trials were then performed, with the peak force of the three contractions recorded.[11]

Assessment of Lower Extremity Performance

Step-Up Test was used and subjects were asked to stair up and down 45cm height step on dominant leg. The number of repetitions was recorded in 3 minute. Dominant and non-dominant sides were evaluated separately. *Single-leg Squat Test* was used to measure the lower extremity muscle endurance. In *Vertical Jump Test*, subjects stands by a wall and reaches up with the hand closest to the wall. Keeping the feet flat on the ground, the point of the fingertips is marked or recorded. The best of three attempts is recorded.[11] In *Side-Step test,* subject stands at a center line, then jumps 30 cm to the side and touches a line with the closest foot, jumps back to the center then jumps 30 cm to the other side, then back to the center. Scoring: One complete cycle is recorded as 1, and half a cycle as 0.5. The score is expressed as the number of repetitions in 30 second.[11]

Statistical Analyses

Statistical analyses were performed using SPSS version 13.0. One-Way ANOVA Test was used for comparing the groups. Tukey test was used as a post-hoc test. Paired-Samples T Test was used to detect improvements within groups. $p<0.05$ was used to denote statistical significance.

RESULTS

Mean age was 21.45±1.12 in the group I, 20.90±0.94 in the group II and 21.66±0.65 in the control group. No significant differences between the groups were found in baseline scores for demographic data (Table 1).

Table 1. Comparison of the Demographic Data of Groups

VARIABLE	RUSSIAN STIMULATION (Group I)	WHOLE BODY VIBRATIONS (Group II)	CONTROLS (Group III)		
	X ± Ss	X ± Ss	X ± Ss	F	p*
Age (years)	21.45±1.12	20.90±0.94	21.66±0.65	2.04	P=0.147
Height(m)	1.72±0.06	1.60±0.07	1.70±0.09	0.366	P=0.696
Weight (kg)	64.45±10.90	65.36±12.30	60.50±16.20	0.431	P=0.654
BMI (kg/m^2)	21.57±2.98	22.59±3.43	20.61±4.48	0.817	P=0.451

*One-Way ANOVA

In the group I, after the 4-week training program, there were no significant differences in quadriceps muscle strength (p>0.05) and in side-step test (p>0.05). Right leg static balance test (p=0.003) and forefoot dynamic balance test significantly increased (p=0.044). Right side Single- Leg Squat Test (p=0.033), right side step up test (p=0.009), left side step up test (p=0.011) and vertical jump test (P=0.046) were significantly improved after training (Table 2).

Table 2. Comparison of Balance and Performance of Russian Stimulation Group (Group I)

VARIABLES	BEFORE TRAINING	BEFORE TRAINING		
	X ± SD	X ± SD	t	p*
BALANCE ASSESSMENT				
Static Balance Two Legs	788.09 ±287.22	787.73±210.22	0.00	P=0.996
Static Balance Right Leg	298.55±199.09	488.64±163.51	-3.99	**P=0.003***
Static Balance Left Leg	489.55±249.35	488.64±163.51	0.01	P=0.992
Static Balance Forefoot	360.00±214.04	349.55±190.55	0.106	P=0.917
Static Balance Hindfoot	428.18±252.25	419.91±188.10	0.10	P=0.922
Static Balance Dominant Leg	1056.60±1155.50	758.82±251.29	0.78	P=0.449
Static Balance Nondaminant Leg	1218.00±990.84	721.91±238.89	1.71	P=0.117
Dynamic Balance Two Leg	1810.50±276.85	1705.10±221.21	1.73	P=0.113
Dynamic Balance Right Leg	830.27±187.93	837.00±155.05	-0.09	P=0.925
Dynamic Balance Left Leg	980.27±192.84	867.91±192.66	1.36	P=0.203
Dynamic Balance Forefoot	957.73±194.54	849.82±165.58	2.30	**P=0.044***
Dynamic Balance Hindfoot	853.00±153.19	855.27±136.94	-0.04	P=0.968
PERFORMANCE ASSESSMENT				
Single- Leg Squat Test (R)	94.09±27.85	111.18±30.77	-2.46	**P=0.033***
Single- Leg Squat Test (L)	90.36±3053	114.09±53.28	-0.07	P=0.065
Step –up Test (R)	60.63±1915	80.27±24.45	-3.21	**P=0.009***
Step –up Test (L)	64.72±22.22	73.72±21.15	-3.10	**P=0.011***
Side-step Test	20.00±13.78	26.09±7.93	-1.46	P=0.174
Vertical –Jump Test	35.09±5.78	37.59±7.23	-0.04	**P=0.046***
MUSCLE STRENGHT				
Quadriceps Femoris (R)	219.27±29.72	226.64±17.89	-0.65	P=0.530
Quadriceps Femoris (L)	216.00±27.19	220.09±13.41	-0.43	P=0.675

*Paired-Samples T Test

Compared to the before and after training, quadriceps muscle strength and side step test scores were not significantly different (p>0.05). Two leg static balance test (p=0.040), right leg static balance test (p=0.034), non-dominant leg static balance test (p=0.025) scores were increased after training in group II. Besides there was a significant differences in right leg side-step test (p=0.027) (Table 3).

Table 3. Comparison of Balance and Performance of WBV Group (Group II).

VARIABLES	BEFORE TRAINING	AFTER TRAINING		
	X ± SD	X ± SD	t	p*
BALANCE ASSESSMENT				
Static Balance Two Legs	771.09 ±250.55	1063.60±480.42	-2.35	**P=0.040***
Static Balance Right Legs	275.82±241.57	475.55±271.83	-2.45	**P=0.034***
Static Balance Left Legs	495.27±238.55	473.55±271.83	0.20	P=0.844
Static Balance Forefoot	396.91±214.84	496.73±225.39	-1.00	P=0.337
Static Balance Hindfoot	374.27±206.37	566.73±458.56	-1.84	P=0.094
Static Balance Dominant Leg	988.91±343.48	782.82±271.84	1.67	P=0.126
Static Balance Nondaminant Leg	1469.00±852.54	802.55±276.62	2.63	**P=0.025***
Dynamic Balance Two Legs	2087.50±705.34	1786.50±503.85	1.67	P=0.125
Dynamic Balance Right Legs	984.27±427.63	926.45±155.05	0.59	P=0.565
Dynamic Balance Left Leg	1103.20±302.12	927.64±203.28	2.21	**P=0.051***
Dynamic Balance Forefoot	1046.10±365.55	892.00±240.79	1.50	P=0.163
Dynamic Balance Hindfoot	1041.30±483.59	962.73±182.13	0.56	P=0.583
PERFORMANCE ASSESSMENT				
Single- Leg Squat Test (R)	80.18±39.34	89.63±13.06	-0.84	P=0.419
Single- Leg Squat Test (L)	84.00±48.44	89.27±14.31	-0.39	P=0.705
Step –up Test (R)	55.09±18.88	80.45±24.45	-2.59	**P=0.027***
Step –up Test (L)	65.27±25.40	71.45±22.19	-0.78	P=0.452
Side-step Test	21.09±22.72	30.45±7.82	-1.62	P=0.136
Vertical –Jump Test	39.00±15.76	42.63±15.13	-1.50	P=0.163
MUSCLE STRENGHT				
Quadriceps Femoris (R)	221.45±51.40	225.64±72.28	-0.26	P=0.795
Quadriceps Femoris (L)	217.45±52.67	221.18±15.73	-0.22	P=0.824

*Paired-Samples T Test

There was a significant differences between before and after training on two leg static balance (p=0.005) and nondominant leg static balance test compared to controls group (p=0.033). Forefoot dynamic balance score (p=0.055), vertical jump scores (p=0.011) and right side quadriceps femoris muscle strength (p=0.021) were increased after training (Table 4).

Table 4. Comparison of Balance and Performance of Control Group (Group III).

VARIABLES	BEFORE TRAINING	AFTER TRAINING		
	X ± SD	X ± SD	t	p*
BALANCE ASSESSMENT				
Static Balance Two Legs	1158.80 ±366.24	890.92±413.25	3.48	**P=0.005**
Static Balance Right Legs	525.00±341.56	550.17±260.22	-0.28	P=0.784
Static Balance Left Legs	629.58±372.77	550.17±260.22	0.77	P=0.456
Static Balance Forefoot	498.00±222.66	381.58±187.00	2.05	P=0.064
Static Balance Hindfoot	656.83±419.29	509.25±324.87	1.41	P=0.184
Static Balance Dominant Leg	947.67±455.03	758.83±340.24	1.33	P=0.210
Static Balance Nondaminant Leg	1062.00±436.65	823.92±240.40	2.43	**P=0.033***
Dynamic Balance Two Legs	2052.00±528.79	1640.30±675.86	1.48	P=0.165
Dynamic Balance Right Legs	995.75±235.00	876.17±287.80	1.79	P=0.100
Dynamic Balance Left Leg	1056.50±315.31	1024.20±469.74	0.37	P=0.715
Dynamic Balance Forefoot	1162.20±401.41	935.67±389.07	2.15	**P=0.055**
Dynamic Balance Hindfoot	890.58±254.49	963.25±381.32	-0.81	P=0.431
PERFORMANCE ASSESSMENT				
Single- Leg Squat Test (R)	102.42±59.48	101.08±21.36	0.09	P=0.926
Single- Leg Squat Test (L)	99.00±61.86	100.25±30.40	-0.07	P=0.939
Step –up Test (R)	82.83±11.52	77.83±14.39	0.89	P=0.390
Step –up Test (L)	75.08±17.61	74.75±13.22	0.07	P=0.944
Side-step Test	28.41±9.95	23.83±5.00	1.33	P=0.210
Vertical –Jump Test	30.91±12.17	34.41±9.60	-3.04	**P=0.011***
MUSCLE STRENGHT				
Quadriceps Femoris (R)	207.42±39.94	229.83±18.44	-2.68	**P=0.021***
Quadriceps Femoris (L)	216.25±42.70	213.58±13.74	0.23	P=0.816

*Paired-Samples T Test

Compared to before and after training scores using by ANOVA in 3 group, there were a statistically significant right side step- up test (F=8.927, p=0.001) and two leg dynamic balance (F=5.920, p=0.007) at the before training. Compared to after training scores there was a statistically significant right side static balance scores (F=3.755, p= 0.035) (Table 5).

Table 5. Comparison of Balance and Performance of Groups.

VARIABLES	RUSSIAN GROUP	WBV GROUP	CONTROL GROUP		
	X ± SD	X ± SD	X ± SD	F	p*
Dynamic Balance Two Legs (Before Training)	1810.50±276.85	2087.50±705.34	2052.00±528.79	5.920	p=0.007* (1-3)** (2-3)**
Step-up Test (Right Leg-Before Training)	60.63±1915	55.09±18.88	82.83±11.52	8.927	p=0.001* (1-3)** (2-3)**
Static Balance Right Leg (After Training)	837.00±155.05	475.55±271.83	550.17±260.22	3.755	p=0.035* (1-2)**

*One-Way ANOVA, ** Tukey 1: Russian Group 2: Vibrasyon Group 3: Kontrol Grubu

Tukey test was performed as a Post-hoc. In the before training, there were statistically significant between the Russian group- control group (p=0.019) and WBV-control group (p=0.013) on the two leg static balance test scores. Besides there were statistically significant difference between the Russian group and control group (p=0.009) and WBV and control group (p=0.001) on the right side step- up test scores. There was statistically significant improvement in Russian group to- WBV group (p=0.051) on right side static balance test scores in after training (Table 5).

DISCUSSION

Seeing, hearing and somatosensoy systems are effective on establishing balance. In addition to these systems, strength and endurance of neck, body and lower extremity muscles are important in establishing and maintaining balance.[3] There are various methods to enhance muscle strength and endurance.[7,12,13] Related studies on the effectiveness of muscle strength and endurance on balance functions and performance.[2,3,5,7,12,13]

At the end of our study, it was observed that in consequence of the 4 weeks training program both the Russian stimulation training and the WBV training improved dynamic and static balance and that their effects on the lower extremity muscle strength, agility and endurance that were determined to be positive, despite the fact that they were not found to be statistically significant. In the control group, on the other hand, increases in two-foot static balance values, agility and muscle strength were observed. However, it was determined that these increases were lower than those observed in the training groups.

These significant changes in control group are considered to be due to the learning of controls group participants the test technique. We believe that the reason the differences found in the training groups were statistically insignificant is due to the insufficient time of training we could carry out. In consequence of the trainings, it was determined that both training methods increased balance and improved muscle power in lower extremity, agility and endurance. In addition, it was observed that the Russian stimulation training was more effective on static balance values in comparison with the WBV training.

An all-round program consisting of strengthening, agility, plyometric and balance exercise for improving balance skills was suggested in several studies.[12,14,15] Baskan et al. reported increase in muscle strength and step up test values among endurance tests in consequence of applying Russian stimulation on knee extensors for 6 weeks and 3 days in a week.[10,16] In our study, statistically significant (p<0.05) increases in knee extensor muscle strength and step up test values were recorded in the 1st group subjected to Russian stimulation.

In another study, comparing the effects of a 3 days a week and 12 week resistance exercise training on knee extensor and elbow flexor muscle groups with the control group showed that the training group had significant increases in knee extensor muscle strength and elbow flexor muscle strength in daily living activities.[17] Paillard et al. reported increase in vertical jump performance in consequence of a 5-week electrical stimulation on quadriceps femoris muscle.[18] The findings obtained in our study are in parallel with those covered in the literature.[12,19]

Whole body vibration training is a neuromuscular method recently being used in muscle strength training of athletes, preventing muscular atrophy and for treatment purposes after injuries. WBV training is used for increasing muscle strength and endurance both for injured and not injured people. Bosco et al. reported increases in leg extensor muscle strength and jump height in consequence of a total of 10 minute WBV training carried out with elite equipment.[20] In another study, it was demonstrated that 1 minute application of WBV training to patients who had stroke resulted in improvements in isometric and eccentric muscle strength.[21] Torvinen et al. reported a 15.7% increase in lower extremity muscle performance (3.2% in isometric knee extensor muscle strength, vertical jump, shuttle run) and balance skills in consequence of 4 minutes WBV application on healthy individuals aged from 24 to 33.[22]

In another study by the same authors, while it was reported that no statistically significant difference could be found in long term knee extensor muscle strength and balance skill after the application of WBV training for 4 months, it was explained that an improvement of 8.5% was determined in vertical jump height.[23] In the meta analysis that examined the effect of WBV on muscle strength no relation could be found between the total time of training and the number of sets.[9] According to the study conducted by Ruiter et al., after an WBV application of 11 weeks no significant differences were found in isometric Quadriceps muscle strength ($p = 0.69$), voluntary activity ($p = 0.55$) and maximal voluntary strength ($p = 0.57$).[17] The findings of our study are found out to be supportive of the findings of other studies. The limitations of our study are the insufficient training period and the number of cases in each group.

CONCLUSION

It was observed that 4 week WBV training and Russian stimulation applied on knee extensors improved balance and also increased lower extremity muscle strength, agility and endurance. The findings of this study demonstrate that all two training strategies may be suited for improving the balance, power, strength and endurance.

Author contributions:
Conception and design: Filiz ALTUĞ
Collection and assembly of data: Tuba CAN AKMAN
Analysis and interpretation of the data: Tuba CAN AKMAN
Drafting of the article: Filiz ALTUĞ
Critical revision of the article for important intellectual content: Uğur CAVLAK
Statistical expertise: Nihal BÜKER
Final approval and guarantor of the article: Filiz ALTUĞ
Corresponding author email: fkural@pau.edu.tr
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