Power Plate Effekte auf die Propriozeption und Stabilität im Knie nach Kreuzbandoperationen.

Moezy et al., Tehran University, British Journal of Sports Medicine (2008)

Ziel der Studie: Untersuchung ob ein Beschleunigungstraining auf der Power Plate einen positiven Einfluss auf die Propriozeption und Stabilität des Knies nach Kreuzbandoperationen hat.

Dauer: 1 Monat

Gerät: Power Plate

Probanden: 20 Athleten nach Kreuzband-Operation (mittleres Alter 23.6 Jahre)

Gruppen: Power Plate Gruppe
Konventionell trainierende Gruppe
(Beide Programme steigern im Zeitverlauf die Intensität und Dauer der Übungen)

Parameter: Posturaler Stabilitätstest, Kniegelenksrepositionstest

Ergebnisse: Die Power Plate Gruppe zeigte im Vergleich zur konventionell trainierenden Gruppe eine signifikante Verbesserung bei allen Messungen der posturalen Stabilitätstests. Weiterhin konnten bei der Power Plate Gruppe Verbesserungen im Kniegelenks-repositionstest beobachtet werden.

Fazit: Nach Kreuzbandoperationen leiden viele Patienten unter einer Instabilität. Die Power Plate Gruppe zeigte im Vergleich zur Kontrollgruppe eine über 22mal größere Verbesserung der Stabilität. Die Befunde deuten darauf hin, dass ein Power Plate Training einen wertvollen Beitrag in der Rehabilitation der Kniestabilität (anterior-posterior) leisten kann.

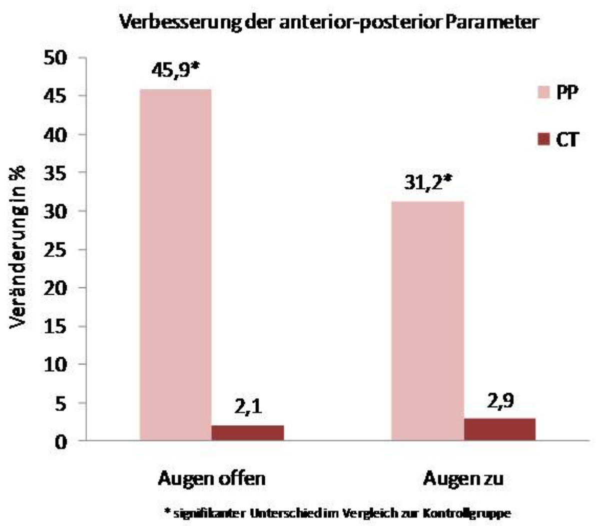

Abb. 1: Die Power Plate Gruppe (PP) zeigt signifikante Verbesserungen der Kniestabilität (anterior-posterior Parameter) im Vergleich zur konventionell trainierenden Gruppe (CT)

A Comparative Study of Whole Body Vibration Training and Conventional Training on Knee Proprioception and Postural Stability after Anterior Cruciate Ligament Reconstruction

Azar Moezy, Gholamreza Olyaei, Mohammadreza Hadian, Mohammad Razi and Soghrat Faghihzadeh

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A Comparative Study of Whole Body Vibration Training and Conventional Training on Knee Proprioception and Postural Stability after Anterior Cruciate Ligament Reconstruction.

Azar Moezy [1], Gholamreza Olyaei [2*], Mohammadreza Hadian [3], Mohammad Razi [4], and Soghrat Faghihzadeh [5]

1-Azar Moezy ,Physical Therapy PhD Candidate, Postgraduate Department, School of Rehabilitation, Medical Sciences/Tehran University. Tehran, Iran.
2-Gholamreza Olyaei, PhD, Professor of Physical Therapy, Postgraduate Department, School of Rehabilitation, Medical Sciences/Tehran University. Tehran, Iran.
3-Mohammadreza Hadian, PhD, Professor of Physical Therapy, Postgraduate Department, School of Rehabilitation, Medical Sciences/Tehran University. Tehran, Iran.
4-Mohammad Razi, Head section of arthroscopy and sports traumatology Department of orthopedic surgery, Iran University of Medical Sciences. Tehran, Iran.
5-Soghrat Faghihzadeh, PhD, Professor and Head of Biostatistics Department of Tarbiat e Modarres University. Tehran, Iran.

* Correspondence to: Dr.Gholamreza Olyaei, Professor, Postgraduate Department.

Address: Postgraduate Department, Rehabilitation Faculty, Tehran University of Medical Sciences, Enghelab Avenue, Pich e Shemiran, Tehran, 1148965141, Iran.
Tel: (0098-021) 77528469,
Fax: (0098-021) 77534133,
Email: olyaeigh@sina.tums.ac.ir

Key Words: Whole body vibration training, Anterior cruciate ligament reconstruction, Postural stability, Proprioception.

ABSTRACT

Objective: To determine the effect of whole body vibration training program (WBVT) in comparison with conventional training (CT) program on knee proprioception and postural stability after anterior cruciate ligament (ACL) reconstruction.
Methods: Twenty athletes with unilateral ACL reconstruction were randomly assigned in two groups; WBVT and CT, all participants received 12 sessions of WBVT or conventional training. Absolute error in joint repositioning test in two target angles (30° and 60°) with Biodex dynamometer, bilateral dynamic postural stability (anteroposterior, mediolateral and overall stability indices) with Biodex Stability System were measured pre and post intervention.
Results: The improvement of postural stability in the WBVT group was significantly greater than CT group ($p \leq 0.05$). The p values of the changing scores of open overall, open anteroposterior, open mediolateral, closed overall, closed anteroposterior and closed mediolateral stability indices were respectively 0.002, 0.010, 0.0001, 0.001, 0.0001, and 0.046. In addition, there were significant differences in all averages of absolute angular error at 60° and 30 º between WBVT and CT groups in both knees (p values were respectively 0.001, 0.001, 0.0001), with exception , the healthy knees, at 30 º target position which was not significant ($p = 0.131$).
Conclusions: Whole body vibration training improved proprioception and balance in ACL reconstructed athletes.

Key Words: Whole body vibration training, anterior cruciate ligament reconstruction, Postural stability, Proprioception.
Abbreviations: ACL , anterior cruciate ligament ; WBVT , whole body vibration training; CT , conventional training ; BSS , Biodex stability system ; COP , center of pressure ; OSI ,overall stability index ; APSI ,anteroposterior stability index ; MLSI ,mediolateral stability index ; AE ,average of absolute angular error.

Proprioception is conscious perception of limb position in space. Many proprioceptors such as ruffini and paccini endings have been found in anterior cruciate ligament (ACL). [1, 2] ACL has a major function as a significant sensory organ which provides proprioceptive information initiating protective and stabilizing muscular reflex as well as mechanical function.[2- 4] ACL injuries not only cause instability and disability in a high percentage of ACL deficient athletes, but also reduce proprioceptive ability and postural stability. Due to proprioception loss in ACL injuries, postural sway may increase. It also seems that any degenerative joint disease following ACL injuries is not purely due to joint instability but also to disruption of proprioception feedback .[5] ACL injuries are a common occurrence in young athletes. Without normal joint stability and proprioception, Athletes often find it difficult to return to normal activity after ACL injuries and reconstruction surgeries; therefore, rehabilitative programs are frequently indicated to return the ACL deficient athletes to the highest level of activity. This means a full range of motion, normal muscle strength, normal agility and coordination, maximum proprioception and stability in knee. [6]
Whole Body Vibration Training (WBVT) is a neuromuscular training method which has been recently developed and introduced as a rehabilitative protocol. [7, 8] The transmission of

mechanical oscillations (30 – 50 Hz) to the body stimulates many biological systems. This in turn may lead to physiological changes at numerous levels as following: stimulations of skin receptors, muscle spindles, joint mechanoreceptors, vestibular system, changes in cerebral activity, and changes in neurotransmitter and hormones concentrations. [9] It has also been suggested that WBVT can affect muscle strength and power, soft tissue flexibility, body balance, neuromuscular conditions, gait parameters and mechanical properties of bones. [7, 10-14]

Because of strong sensory stimuli of WBVT on muscle receptors, it might also be a stimulus for other proprioceptors. [15] Some studies have analyzed the effect of WBVT on muscle performance and balance in normal subjects. Torvinen et al [12] presented evidences that after 4 minutes of WBVT in young adults, 15.7% improvement in body balance have been observed; however, no effect after 4 months training has been reported. [16]

Verschueren et al [17] reported that postural sway after a fast abduction of arm following 6 months WBVT have reduced in postmenopausal women. Schuhfried et al [9] found the positive effect of WBVT in postural control of moderately disabled multiple sclerosis patients. Bogarets et al [15] declared that WBVT was associated with reduced fall frequency in moving platform and improvement in some aspects of postural control in older individuals. Van Nes et al [18] in a study on unilateral chronic stroke patient concluded that WBVT may be a candidate to improve proprioceptive control of posture in stroke patients. Fontana et al [19] had studied the effect of WBVT on lumbosacral proprioception; she showed a single 5 min of WBVT combined with a static closed chain exercise improved lumbosacral proprioception. Melnyk et al [20] indicated a single WBVT had a beneficial effect on functional knee stability in normal subjects.

However, there is little scientific evidence with regard to the effects of WBVT on proprioception and postural stability in ACL reconstructed athletes. Accordingly, the aim of this study was the comparison of the effects of WBVT program and conventional therapy on knee proprioception and postural stability in ACL reconstructed subjects.

METHODS

The study was a single blind randomized clinical trial which was approved by the Ethical Committee of Medical Sciences/Tehran University and each subject provided informed written consent. Subjects were introduced to Sport Physical Therapy Clinic between May and October 2006.

Participants

Forty subjects were primarily referred by orthopedic surgeon; seventeen subjects did not fulfill the inclusion criteria and three subjects were also excluded in the next stage (fig 1). Main participants were twenty male athletes who underwent an arthroscopically assisted surgery for ACL reconstruction with central bone – patellar tendon –bone approach.All of the participants fulfilled the inclusion criteria as following: An ACL reconstruction surgery 3 month before, competitive athletes of national or international level, no previous or concomitant injury or surgery on the relevant knee and other joints, no history of surgery or traumatic injuries to the contra lateral limb, full active range of motion on reconstructed knee, no history of a medical problems such as heart disease that limited activities and no history of WBVT contraindications for participants of WBVT group. In addition, all subject released from formal rehabilitation program which was the same for both groups before participation. Participants were randomly allocated in WBVT and CT (12 and 11 respectively). Before participation, all subjects filled out the written informed consent.

Figure 1 Study profile for participants in WBVT and CT groups.

Testing Procedures

Participants were familiarized with testing procedures two days before the testing session.
In all sessions, each subject was dressed in short, without shoes and socks. Our evaluating systems were calibrated before the sessions in accordance with the manufacturer's instructions. The testing session started with a 10-minute jogging warm up program on a Treadmill (Technogym, Italy) and lower body stretching exercises.

Postural Stability Test

Postural stability was evaluated by Biodex Stability System (BSS), (Biodex Medical Systems, Inc, and Shirley, NY, USA). The BSS with specialized software (Version 3.1) enables to measure the deviation of the center of pressure (COP) during static conditions, and measuring the degree of tilt during dynamic conditions. The COP can be used to evaluate the amount of sway of the center of gravity over the foot during stance. Postural stability was measured by overall, anterior–posterior, and medial–lateral stability indices (OSI, APSI and MLSI, respectively).A high score indicates poor balance. [22, 23]
The BSS was shown to be reliable in previous studies. Schmitz and Arnold reported intraclass correlation coefficient (ICC) values for dominant single limb stance ranging from 0 .8 to0 .43, using a decreasing stability level from 8 to 2 over 30 s. [23] Pincivero et al. reported ICC values of 0.6 (level 8) to 0.95 (level 2) in healthy subjects. [24] We also confirmed reliability of BSS during our pilot study (table 3).

Subjects were requested to step on platform and assume a comfortable position on it while maintaining slight flexion in the knees (15°). When subjects felt comfortable, the platform was released, at this stage, the subjects were asked to change their position so that they got balanced standing on the platform, then the platform was locked and the position of their feet were recorded. The testing procedure consisted of progressively decreasing the stability of platform from level 8 to 4 in 25 seconds.

Bilateral stance position was evaluated with opened and closed eyes (respectively). Three trails of tests in either condition were performed and 3 minute rest was between each condition. In opened-eye condition, subjects were requested to look ahead at a spot marked directly in front of them.

Knee Joint Reposition Test

Evaluation of proprioception was performed with joint reposition test. The position sense of the knee was tested by examining the ability of subjects to reproduce actively an angle at which the joint had been placed before in non weight-bearing position.

Knee position sense was performed on the Biodex Dynamometer (Biodex Medical Systems, Inc, Shirley, NY, USA with software version 3.27) using this system's electrogoniometer (sensitive to 1° increments) to record the angles of knee movement during testing. The Biodex isokinetic dynamometer has been found to be a valid and reliable device for torque and position measurements. [25, 26] The reliability of Biodex dynamometer in knee reposition test was measured during our pilot study (table 3).

The subjects were seated up straight in the Biodex chair with the seat adjusted approximately 5 cm from popliteal fossa. To eliminate visual input during testing, subjects were blindfolded and an air splint was positioned around the leg to reduce cutaneous sensory input. The knee of the tested leg was aligned with the axis of the dynamometer and the thigh was secured to the seat with a strap. The tibial pad was secured to the shank 3 cm superior to the lateral malleolus. Then the subjects were asked to extend actively the knee from starting position (90 ° knee flexion) to target angle (60 ° knee flexion) .When the target angle was reached, the Biodex held the position for 5 seconds, then returns to starting position. After a short interval, the subject was requested to reproduce actively the target angle, when reproducing, he pressed the hold button. The same procedure was used to evaluate the active reposition test at 30° of knee flexion. Both knees were tested and each test trail was conducted 5 times for each target angle. The absolute angular error, the absolute difference between the target angle and the subject's estimated test angle, of the 5 trails was measured in both knees and the average of absolute angular error was recorded in reconstructed (ReAE) and uninjured (UnAE) knees.

Interventions

All subjects in both groups followed a definite physiotherapy program immediately after surgery for 12 weeks. At the beginning of 12 week, subjects were randomly assigned in two groups (WBVT and CT groups) and began three-weekly training program for one month. The WBVT group did exercise on vibration platform (Powerplate, USA), while they were barefoot. Table1 shows the details of WBVT program. The subjects of CT group were continued the conventional strengthening exercises program (table 2), flexibility training for both lower limbs, proprioceptive training on tilt board progress from two legged to one legged positions and also from opened to closed eye. The subjects had a 10 minute warm up prior their exercises.

Table 1 Characteristic of the WBVT program

Session	Duration of each set (sec)	Frequency z)	Amplitude*	Rest sec)	Modalities	WBVT Duration (min)	Sets of exercises** a	b	c	d	e	f	g	h	i
1	30	30	low	60	static	4	2	2	1		1			1	1
2	30	30	low	60	Static	5.5	3	3	2		1			1	1
3	30	30	low	60	Static &Dynamic	6.5	3	3	3		1			1	2
4	30	35	low	50	Static &Dynamic	8	3	3	3	1	2		1	1	2
5	45	35	low	50	Static &Dynamic	12	2	2	3	2	2		1	2	2
6	45	35	low	50	Static &Dynamic	12	2	2	3	2	2		1	2	2
7	45	40	high	40	Static &Dynamic	13.5	2	2	3	2	2	1	2	2	2
8	45	40	high	40	Static &Dynamic	15	2	2	3	2	3	1	2	2	3
9	45	40	high	40	Static &Dynamic	15	2	2	3	2	3	1	2	2	3
10	60	40	high	30	Static &Dynamic	16	1	1	2	2	2	2	2	2	2
11	60	50	high	30	Static &Dynamic	16	1	1	2	2	2	2	2	2	2
12	60	50	high	30	Static &Dynamic	16	1	1	2	2	2	2	2	2	2

* Amplitude: High = 5 mm, Low = 2.5 mm

** Exercises:

a. Static position, standing with knees lightly bent, feet in the middle of platform and slightly apart, back straight
b. Static position, one leg stance with knee lightly bent, foot in the middle of platform, back straight
c. Static or Dynamic position, Mini Squat
d. Static or Dynamic position, One Leg Mini Squat
e. Static or Dynamic position, Deep Squat
f. Static or Dynamic position, One Leg Deep Squat
g. Static or Dynamic position, Wide Stance Squat
h. Static or Dynamic position, Lunge , One foot in the middle of platform , back straight, Bend the knee about 90 degrees
i. Static or Dynamic position, Toe Standing

Table 2 Characteristic of the conventional strengthening program

Session	Muscle groups	Sets for each muscle groups	10RM*	Rest (sec) Between sets	No of exercises for each muscle groups
1	Hip abductors & adductors	3	10RM	60	8-10
2	Hip abductors & adductors	3	10RM	60	8-10
3	Hip abductors , adductors & flexors	3	10RM	60	8-10
4	Hip abductors , adductors , flexors & extensors	3	10RM	50	8-10
5	Hip abductors , adductors , flexors , extensors &	4	10RM	50	8-10
	leg press	3			
6	Hip abductors , adductors , flexors ,extensors ,	4	10RM	50	10
	leg press & leg curl	3			
7	Hip abductors , adductors , flexors ,extensors , leg press & leg curl	4	10RM	40	10
8	Hip abductors , adductors , flexors ,extensors , leg press & leg curl	4	10RM	40	10
	Mini squat	3	1/10BW**		
9	Hip abductors , adductors , flexors ,extensors ,	4	10RM	40	10
	leg press & leg curl	3			
	Mini squat		1/8-1/10BW		
10	Hip abductors , adductors , flexors ,extensors ,	4	10RM	30	10
	leg press & leg curl	3	1/8BW		
	Squat				
11	Hip abductors , adductors , flexors ,extensors , leg press & leg curl	4	10RM	30	10
	Squat		1/6-1/8BW		
12	Hip abductors , adductors , flexors ,extensors , leg press & leg curl	4	10RM	30	10
	Squat		1/6BW		

*10 RM =10 Repetition Maximum, 10RM in a given exercise is the 10 repetitions in a definite load done in perfect form.10RM was changed every week.
**BW =Body weight

Statistical Analysis

The Statistical package for the Social Sciences (SPSS, version 11.5, SPSS Inc, and Chicago, IL) was used to conduct analysis. Normal distribution of data was determined by One-Sample Kolmogorov-Smirnov test and parametric tests were used to analyze the data. Paired-sample t test was applied to determine the differences at each group. Independent sample t test was used to compare the baseline measurements between the groups at the beginning and at the end of training. Between groups differences were analyzed by mean of independent t test on change scores of both groups after post test .The change scores of a group was defined as the increase or decrease of each variable from pre test to post test. The level of significance was set at $p \leq 0.05$. To assess the Intratester reliability of above-mentioned tests, 11 subjects with same approach of ACL reconstruction surgery had repeated measurements 1 week apart.
Test-retest reliability of all measurement was assessed using Interclass correlation coefficients (ICC) with 95% level of confidence. Absolute reliability (standard error of measurement) is also measured (table 3).

Table 3 Interclass correlation (ICC) coefficients (95%) and Standard Error of Measurement (SEM) values

Tests	ICC Coefficient (95%) (Upper-Lower Bound)	SEM
Opened eye OSI	0.9876 (0.9546 – 0.9966)	0.19
Opened eye APSI	0.9856 (0.9484 – 0.9962)	0.19
Opened eye MLI	0.6046 (0.0439 – 0.8756)	0.57
Closed eye OSI	0.9734 (0.9046 – 0.9928)	0.53
Closed eye APSI	0.9185 (0.7274 – 0.9774)	0.66
Closed eye MLI	0.8228 (0.4692 – 0.9490)	0.92
ReAE * 60 °	0.9332 (0.7725 – 0.9816)	2.09
UnAE ** 60°	0.9868 (0.9517 – 0.9964)	1.33
ReAE 30°	0.9862 (0.9498 – 0.9963)	0.76
UnAE 30 °	0.9878 (0.9555 – 0.9967)	0.76

* ReAE = average of absolute angular error in the reconstructed knees

** UnAE = average of absolute angular error in the uninjured knees

RESULTS

There were no significant differences between WBVT and CT groups for the demographic variables (table 4), indicating that the groups were well matched.
In both groups, subjects acquainted very rapidly with the training protocols. There were no reports of adverse reactions and discomfort in both groups. All subjects of WBVT group experienced the vibration training as effective, enjoyable and also fatiguing modality for exercise therapy. During the second and third weeks of training, three subjects withdrew (2 in WBVT group and 1 in CT group) due to death of his mother, travel and accident. All remaining subjects' completed 1 month training and evaluating sessions.

Table 4 Subjects characteristics

	WBVT Group (n=10) mean(SD)	**CT Group (n=10) mean(SD)**
Age (yr)	24.51 (3.38)	22.70 (3.77)
Height (m)	1.74 (0.05)	1.78 (0.07)
Weight (kg)	74.30 (10.61)	78.00 (10.12)
BMI (kg/m^2)	24.51 (3.38)	24.62 (2.78)
Time from injury to surgery (month)	5.6 (3.02)	5.1 (3.54)

Pre Test Results

Independent- sample t test revealed no significant differences between two groups at the beginning of the study.

Post Test Results

WBVT Group

In the WBVT group, there were significant differences in overall stability, anteroposterior and mediolateral indexes in opened and closed eye conditions between pre and post tests ($p \leq 0.05$).The mean absolute error for target of 60º was 6.00 º then changed to 2.53 º after vibration training which was significantly more than the values of CT group. The same results were acquired for 30 º in the WBVT group. In the WBVT group, there were significant differences in the averages of absolute angular error between pre and post tests in reconstructed knees at both 30 ° and 60 ° ($p \leq 0.05$), but in the healthy knees, at 30 ° degree there was no significant difference in the average of absolute error (Table 5).

Table 5 Training effect within WBVT group (n=10)

Tests	Pre Test	Post Test	P value
	Mean (SD)	Mean (SD)	
Opened eye OSI	3.88 (1.79)	2.05 (1.03)	0.001*
Opened eye APSI	3.16 (1.85)	1.71(0.89)	0.008*
Opened eye MLSI	2.42 (0.29)	1.55 (0.91)	< 0.0001 *
Closed eye OSI	10.19 (2.92)	6.99 (1.61)	< 0.0001*
Closed eye APSI	8.24 (2.49)	5.68 (1.55)	< 0.0001*
Closed eye MLI	6.33 (2.21)	4.15 (1.32)	0.003*
ReAE 60°	6.00 (1.88)	2.53 (0.76)	< 0.0001*
UnAE 60°	8.70 (3.70)	2.83 (0.97)	< 0.0001*
ReAE 30°	5.23 (1.68)	3.30 (1.97)	0.067*
UnAE 30°	7.16 (2.65)	2.77 (1.49)	< 0.0001*

* Significant difference between pre test and post test values, $p \leq 0.05$

CT Group

In the CT group, there were significant differences in opened and closed eyes Overall stability indexes and also a significant difference in closed eyed Mediolateral index between pre and post tests ($p \leq 0.05$). There were no significant differences in the averages of absolute angular error between pre and post tests in both knees and at both target positions (Table 6).

Table 6 Training effect within CT group (n=10)

Tests	Pre Test	Post Test	P value
	Mean (SD)	Mean (SD)	
Opened eye OSI	3.40 (0.98)	3.21 (0.94)	0.010*
Opened eye APSI	2.71 (1.05)	2.66 (1.09)	0.310
Opened eye MLI	2.24 (0.84)	2.23 (0.86)	0.985
Closed eye OSI	10.66 (2.43)	10.01 (2.41)	0.001*
Closed eye APSI	8.63 (2.18)	8.38 (2.43)	0.390
Closed eye MLI	6.75 (1.61)	5.92 (1.62)	0.031*
ReAE 60°	7.00 (0.95)	6.57 (0.89)	0.380
UnAE 60°	7.00 (1.04)	6.24 (0.93)	0.203
ReAE 30°	6.24 (0.88)	5.97 (0.75)	0.604
UnAE 30°	6.77 (0.88)	6.17 (0.87)	0.095

* Significant difference between pre test and post test values, $p \leq 0.05$

Comparison between Training Groups

The improvement of postural stability in the WBVT group was significantly greater than CT group. In the WBVT group, the changing score of all stability indexes between pre and post test were much greater than the values in the CT group (Table 7).Moreover, there were significant differences in all averages of absolute angular error between WBVT group and CT group in both knees, except in the healthy knees, at 30 º target position which was not significant.

Table 7 Comparison between Training Groups

Tests	WBVT Group	CT Group	P value
	Changing Score Mean (SD)	Changing Score Mean (SD)	
Opened eye OSI	1.83 (1.20)	0.18 (0.18)	0.002*
Opened eye APSI	1.45 (1.36)	0.058 (0.17)	0.010*
Opened eye MLI	0.87 (0.47)	0.002 (0.32)	< 0.0001*
Closed eye OSI	3.19 (1.78)	0.65 (0.41)	0.001*
Closed eye APSI	2.57 (1.24)	0.25 (0.89)	< 0.0001*
Closed eye MLI	2.18 (1.72)	0.83 (1.02)	0.046*
ReAE 60°	3.47 (1.88)	0.44 (1.49)	0.001*
UnAE 60°	5.87 (3.43)	0.50 (1.15)	0.001*
ReAE 30°	1.93 (2.93)	0.27 (1.58)	0.131
UnAE 30°	4.40 (1.87)	0.60 (1.02)	< 0.0001*

* Significant difference between pre test and post test values, $p \leq 0.05$

DISCUSSION

Whole body vibration is a new kind of somatosensory stimulus for proprioception with a long lasting postural effect on healthy subjects. [27] There are several reports about the effect of WBVT on postural balance, some supported its positive effect [9, 12, 15, and 18] and some did not. [16, 21] However, there is a lack of scientific support about the effects of WBVT on proprioception especially on knee proprioceptors after ACL reconstruction. In this study, a WBVT protocol was used for postoperative rehabilitation of athletes who had undergone ACL reconstruction in comparison with conventional training. The principal finding in this investigation was the positive effects of WBVT in improvement of knee proprioception and postural balance. The results of this research showed that WBVT increased postural stability and proprioceptive function in ACL reconstructed athletes.

Based of the results of current study, it might be suggested that several types of receptors are sensitive to these mechanical stimuli. The most important effects of vibration are stimulation of extroceptives receptors on the sole of foot (Merkel, Meissner, Ruffini receptors). Also stimulation of proprioceptive receptors could initiate stretch and cutaneous reflexes and hence increase muscle strengths.

The nature of this repetitive stimulation might be a rearrangement of balance control strategies, which results in improvement of postural stability. [9] Based on this investigation, the indices of postural stability in WBVT group was significantly improved. This finding is in agreement with the results of authors who had studied the positive effects of vibration in patients' balance.[9,15,18] This might be due to positive effects of WBVT on muscle strengths, improved synchronization of firing of the motor units and improved co contraction of synergist muscles which could render to better balance control strategies in patients. [18, 28] The results of our study demonstrated that WBVT was very pleasant for all subjects. The acceptance of the program by all participants of WBVT group was encouraging. In addition to OSI, APSI and MLSI were also measured to evaluate the postural control. Based on our results, there was a significant difference in all postural stability indices between WBVT group and CT group, more improvement in stability of WBVT subjects. In WBVT group, all stability indices demonstrated a significant difference from pretest to post test. In CT group, there were significant differences in OSI in both opened and closed eye and also closed MLSI. It seems WBVT had a greater somatosensory effect for balance control than conventional training. Some improvement in lumbosacral proprioception had been reported after WBVT. [19]
Our results revealed a significant difference in absolute angular error results in the reconstructed knees in both WBVT and CT groups. The WBVT group showed significant differences in the results of joint repositions test, but within CT group, there were no significant differences. In the WBVT group, there was a significant difference in healthy knees between pre and post tests at 60°. WBVT increased the difference between the absolute angular errors of reconstructed knees. Also, the beneficial effect of WBVT on functional knee stability is reported in normal subjects. [20]
The results of pervious studies suggested that the patients who had undergone ACL reconstruction surgery had bilateral deficits in neuromuscular control of knee. [29-31] Thus re-establishing the mechanical function of ACL by reconstruction and restoring normal joint function with proper rehabilitation program especially after surgery till 6 months may improve knee kinematics and enhance proprioception. [2] WBVT may be a new candidate for the rehabilitation after ACL reconstruction. However, further researches for elucidation of the effects of WBVT on knee proprioception are recommended. Furthermore, future investigations should be directed to find out the most efficient WBVT protocols. In addition, more clinical studies are required to follow the long lasting effects of vibration in ACL deficient athletes.
This study had several limitations. The sample size of current study was small and we had no follow up period due to un-calibration of Biodex system**.** In addition, there was no previous investigation on this topic and therefore, the current exercise protocol for WBVT might not be optimal.

CONCLUSION

It seems that WBVT and CT methods are effective in rehabilitation of ACL reconstruction. The results of this study showed that WBVT was associated with the more improvement of joint stability and balance. The positive effect of WBVT, its short time of training and satisfaction of subjects in the present study support the need for future research on this training as a new method in rehabilitation of ACL injuries.

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What is already known on this topic

- ACL injuries not only cause instability and disability in a high percentage of ACL deficient athletes, but also reduce proprioceptive ability and postural stability.
- Whole body vibration is a new kind of somatosensory stimulus for proprioception with a long lasting postural effect on healthy subjects

What this study adds

- It seems WBVT had a greater somatosensory effect for balance control than conventional training.
- The principal finding in this study was the positive effects of WBVT in improvement of knee proprioception and postural balance.
- WBVT may be a new candidate for the rehabilitation after ACL reconstruction.

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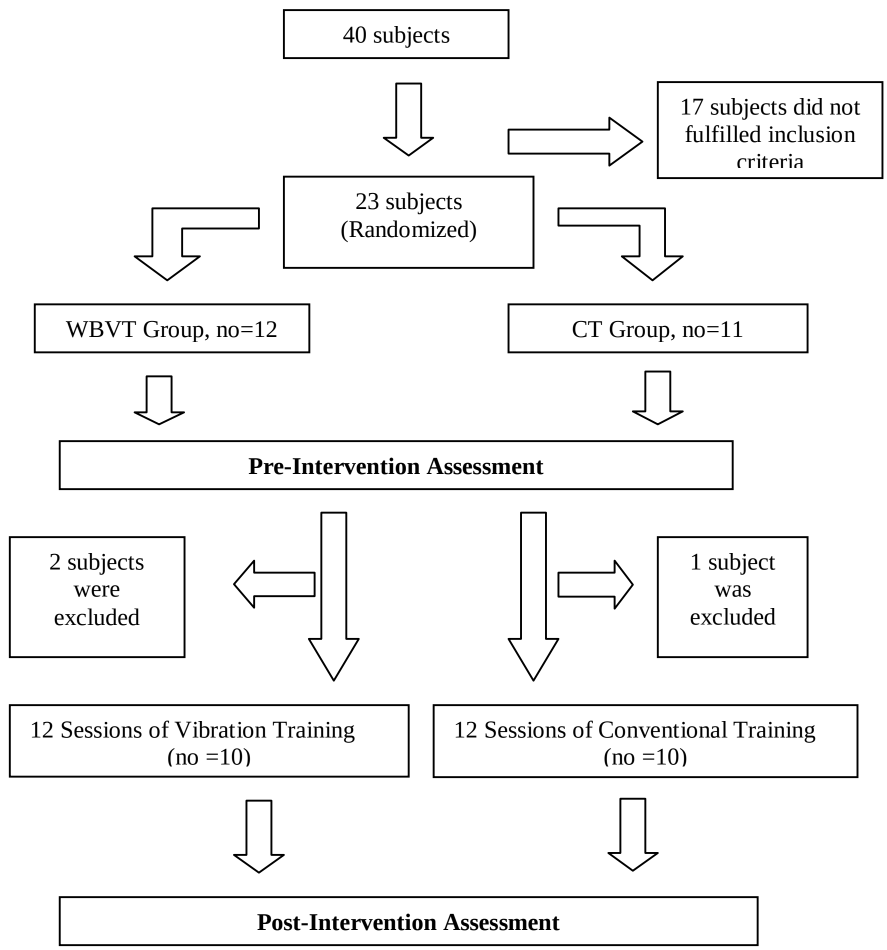

Figure 1 Study profile for participants in WBVT and CT groups.