Compare the Effect of Traditional and Virtual Reality Training on Subjective-sense of Instability and Balance in Basketball-players with Functional Ankle Instability: Matched Randomized Clinical Trial

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ABSTRACT

Background: Functional ankle instability (FAI) is a common injury. Traditional training improved the reported balance impairment and subjective sense of instability in athletes with FAI.

Objective: This study aims to compare the effects of traditional and virtual reality training on a subjective sense of instability and balance in athlete with FAI.

Material and Methods: In this single-blinded matched randomized clinical trial design, Fifty-four basketball players were randomly assigned in the virtual reality (n=27) or control (n=27) groups. All athletes performed 12 sessions Wii exercises or traditional training in the virtual reality and the control group, respectively, for three days a week. To assess the subjective-sense of instability and balance, we used Cumberland Ankle Instability Tool (CAIT) and Star Excursion Balance Test (SEBT), respectively. Measures were taken at pre- and post-test and one month after training as a follow-up. The between-group comparisons were done by the analysis of Covariance.

Results: At the pre-test, the CAIT score was 22.37, 22.04 in the control and virtual reality groups, respectively and at the post-test, these scores increased to 26.63, 27.26. The involved limb showed significant differences in posteromedial and posterior directions of the SEBT and CAIT score in the post-test and in the posterior direction and CAIT score in the follow-up. The virtual reality group had better performance than the control group but the effect size is small (cohen's d<0.2).

Conclusion: Based on our results, both training protocols were effective in reducing the subjective-sense of instability and improved balance in athletes with FAI. Moreover, virtual reality training was very attractive for the participants.

Citation: Mohammadi N, Hadian MR, Olyaei GhR. Compare the Effect of Traditional and Virtual Reality Training on Subjective-sense of Instability and Balance in Basketball-players with Functional Ankle Instability: Matched Randomized Clinical Trial. *J Biomed Phys Eng*. 2023;13(3):269-280. doi: 10.31661/jbpe.v0i0.2007-1146.

Keywords

Ankle Injuries; Virtual Reality; Joint Instability; Star Excursion Balance Test; Cumberland Ankle Instability Tool

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Received: 24 July 2020
Accepted: 20 August 2020

Introduction

Ankle sprains cause a lot of limitations in various areas of activity, especially sport. Functional ankle instability (FAI) causes the person to feel the ankle "giving way" as a result of repeated ankle sprains [1]. FAI is the main cause of decreased muscle strength and impaired balance. These symptoms can limit physical and daily life activities for years after injury and reduce the quality of life [2]. The sense of balance is a key factor in many activities and athletic success [3].

Cumberland Ankle Instability Tool (CAIT) is a simple, reliable, and valid tool for classifying individuals with FAI (ICC2, 1=0.96) [4, 5]. A score of 24 or lower in CAIT is defined as FAI [6, 7]. The effectiveness of traditional therapies had been reported to reduce the feeling of instability in individuals with FAI [8, 9].

Star Excursion Balance Test (SEBT) is a set of 8 lower limb reaching tasks that are useful in identifying lower limb functional impairment [10, 11]. SEBT is a functional screening tool designed to assess the dynamic stability of the lower limbs, monitor rehabilitation progress, assess impairment caused by injury, and identify high-risk athletes for lower limb injuries [12].

SEBT challenges the ability of postural control, strength, range of motion, and proprioception. The farthest distance the individuals can touch with one limb while maintaining the balance on the opposite limb is the best performance for them. The ability of the limb to reach the farthest distance requires a combination of strength, balance, and better movement on the opposite limb [10]. The improvement of performance in SEBT was reported in women soccer players after neuromuscular training, including lower limb stability and strength exercise [12].

Individuals interact with virtual environments in a virtual reality program and the advantages are that the movements are properly observed, evaluated, and controlled. These, in turn, make the virtual reality program a good protocol and intervention method in neurological rehabilitation. Although the positive effects of traditional training were reported to improve balance, these programs had some disadvantages in terms of the boring and incapability of motivating individuals [1]. Wii games provide lower limb movement and challenge balance; therefore, they can be used in rehabilitation programs during the patient's recovery [13]. Wii provides a new way of interacting with games to improve physical activity. Consequently, it guides an individual's motor response in a general or specific way to train motor abilities such as balance and range of motion [14]. Besides, the Wii balanced training program compared to traditional training is recommended to improve the strength of the ankle muscles in patients with FAI [15].

Balance impairment in an individual with FAI can subsequently cause ankle sprains [16, 17]. Therefore, balance and coordination exercises are often used to prevent the recurrence of ankle sprains. Despite the introduction of many rehabilitation protocols, recurrent ankle sprains often occur [18-21]. More research is needed in terms of training and recommendations to reduce ankle sprains.

One study found that virtual reality programs improved balances in subjects with FAI [1]. Improved balance after traditional training had also been reported in individuals with ankle instability [18-21]. However, no comparison had been made between the effect of these two different approaches of exercises (i.e. traditional and virtual reality exercise), thus this study aims to compare the effect of traditional and virtual reality training on the subjective sense of instability and the balance of athletes with FAI. The following hypotheses were tested in the current study: 1. both training methods improved the balance and reduced the subjective sense of instability 2. Virtual reality training was more effective than traditional training 3. These improvements were observed until follow-up in each group.

Material and Methods

Design

This is an original study with the single-blinded matched randomized clinical trial design.

Subjects

The subjects were selected by non-probability convenient sampling method. The sample size was determined through the pilot study which recruited 14 subjects in each group. Based on the pilot study, with a power of 80% and a confidence interval of 95%, fifty-four male basketball players were surveyed in this study. The subjects with age between 19 and 25 had at least one significant unilateral inversion sprain of either ankle within the last year, followed by more than one repeated injury or the perception of ankle "giving-way" or instability within the previous 12 months. The CAIT score was less than 24, and there is no evidence of mechanical instability (assessed by the talar tilt and anterior drawer tests), no ankle surgery, no vestibular or respiratory disorder, not taking any medication with possible effects on neurocognitive function or functional performance, no cognitive deficit (a score of 23 or less in Mini-Mental State Examination (MMSE)), and no participation in other rehabilitation exercise programs [1, 21-23]. In both groups, athletes were excluded if they reported any pain or were reluctant to continue the tests [1, 21-23].

Ethical Consideration

The guidelines of the Declaration of Helsinki and Tokyo for humans were followed by this research [24]; and also the Ethical Committee of Tehran University of Medical Sciences approved the protocol of the study and informed consent forms signed by all athletes. This study was registered in the Iranian Registry for Clinical Trial (registration number: IRCT20090301001722N19) and supported by Tehran University of Medical Sciences. The study took place at the Physical Therapy Clinic School of Rehabilitation TUMS from May 2018 to July 2019.

Procedure

Fifty-four athletes were grouped into 27 matched pairs. Each athlete completed a general questionnaire that provided background information, including sex, age, weight, height, and duration of physical activity. This information was used to match the subjects. In the matched pairs design, each pair randomly was assigned (block randomization) in two equal Virtual Reality (VR) and control groups using the Random Allocation Software. The preferred limb used to kick a ball was the criterion for determining the dominant limb [22]. Subjects were asked to complete CAIT for the involved limb. This evaluation tool, CAIT, includes nine items that objectively assess the ankle pain, ankle instability in daily activities, and recovery time after an ankle sprain; a score of 24 or lower is defined as FAI [6, 7]. Each individual performed five minutes warm-up on a stationary bike [25]. Orders of the test were random and the subjects were allowed to do two practice trials of the SEBT to learn how to perform the test. The subjects, with bare feet, performed seven trials of the SEBT, and the last three reaches in each direction were recorded. Fifteen and thirteen seconds of rest were considered between trials and directions, respectively, to decrease the chances of fatigue [11]. The mean score was considered the analysis for each athlete [25, 26]. Both limbs were assessed.

SEBT

The SEBT was performed with the individual standing with the test foot at the center of a grid placed on the floor and touching the furthest distance with the other foot. The test was performed in eight directions: anterior (Ant), anteromedial (AM), medial (Med), posteromedial (PM), posterior (Post), posterolateral (PL), lateral (Lat), and anterolateral (AL) (Figure 1) [26].

Measurements were performed at pre-test, post-test (after training), and follow-up (four weeks after training) periods as shown in the flow chart of study in Figure 2. The tests were conducted by a physiotherapist who was blind to the assignment and type of training of athletes, performed by the second physiotherapist.

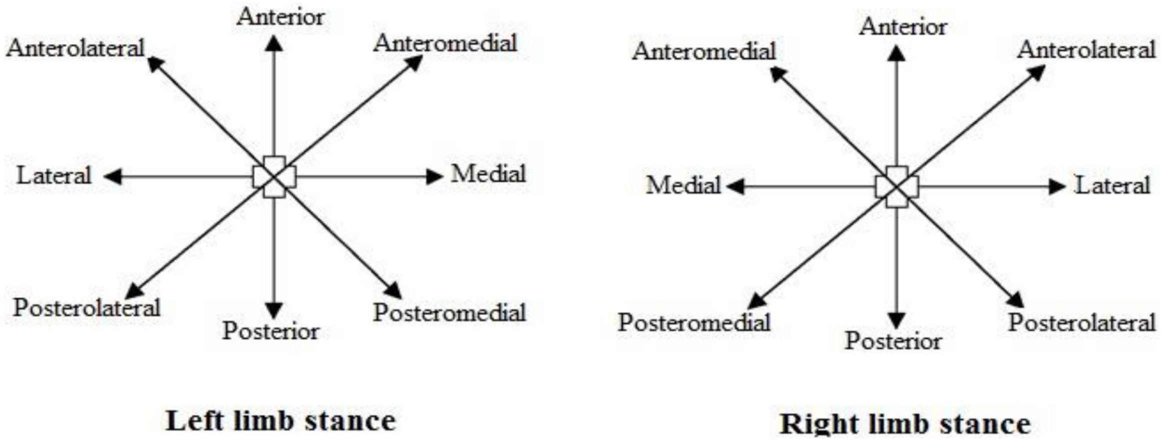

Figure 1: Eight directions of the Star Excursion Balance Test.

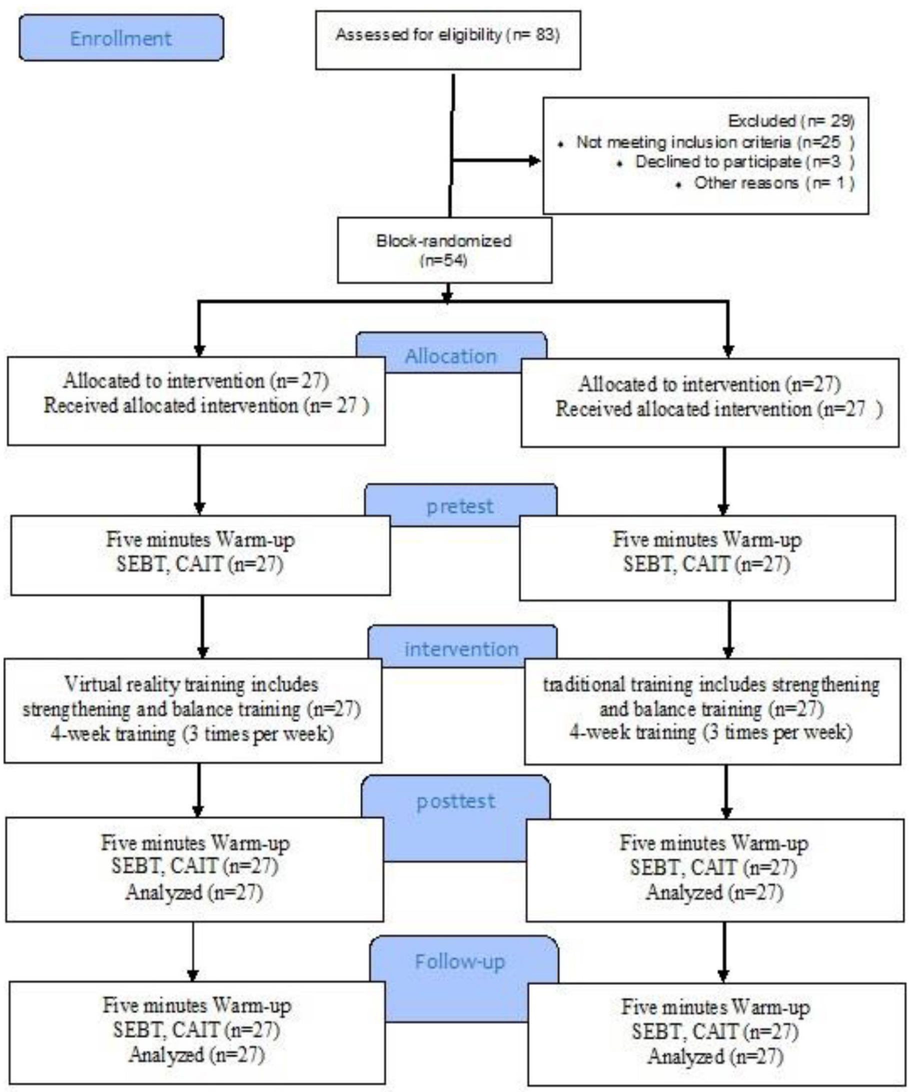

Figure 2: Flow chart of the study.

Interventions

Four-week training (three days per week, 12 sessions) was conducted for both groups. In the VR group, the athletes performed Wii Fit Plus games, including strengthening exercises and balance training games, as seen in Figure 3 [27].

In the control group, the athletes performed traditional exercises, including plantar flexion, dorsiflexion, inversion, and eversion movements with Thera-Band and exercising with the balance board. Training with Thera-Band was performed in three sets with ten repetitions for each movement and was performed with red, green, blue, and black Thera-Bands, in the first, second, third, and fourth weeks, respectively. To determine Thera-Band resistance during the ankle movements, 70% of leg length was considered as Thera-Band length, for each athlete. The athletes stood on the balance board and moved the front edge against the floor then moved the board back, in the first week. In the second week, they moved the left and right edges against the floor, and in the

Figure 3: Wii Fit Plus games including balance training games: A) Soccer heading, B) Ski slalom, C) Tight rope walk, D) Table tilt and strengthening exercises: E) Single leg extension, F) Sideways leg lift, G) Single leg twist, H) Rowing squat).

last two weeks, circulating movements were performed. During exercise, the board should not touch the floor and lasted for 15 s and the rest times were 10 s, and these trends were repeated 10 times.

The SPSS statistical program was used to report the statistical analyses. The standard deviations and means of all data were calculated. Normal distribution was checked by the Kolmogorov-Smirnov test. The between-groups and within-group comparisons were done using the Analysis of Covariance (ANCOVA) and repeated measures analysis of variance, respectively. In within-group comparison for the significant results, to compare performance differences between pre-test, post-test, and follow-up assessments, Bonferroni post-hoc test was performed. Statistical significance was set at $P<0.05$.

Results

All 54 athletes were assessed and analyzed. Demographic characteristics for each group were reported in Table 1 and there was no significant difference in terms of age, height, weight, and duration of physical activity, between the two groups. For each group (27 athletes), the mean and standard deviations of variables for pre-test, post-test, and follow-up assessments for involved and uninvolved limbs were shown in Tables 2 and 3, respectively. The distribution of data was normal. The between-group comparison showed no significant differences for uninvolved limbs (Table 3). In between-group comparison, for involved limb, significant differences were observed in PM and Post directions of the SEBT and CAIT score in the post-test and in Post direction and CAIT score in the follow-up (Table 2). The VR group had better performance than the control group, but the effect size was small (d<0.2). Therefore, we concluded that both protocols improved the balance and the subjective sense of instability.

In the within-group comparison for involved limb, there were significant differences in PM, Post, PL, AL directions of SEBT, and CAIT score in both groups (Table 4). AM and Lat directions of SEBT showed a significant difference in the control and VR groups, respectively (Table 4). Medium effect size in PM direction in the VR group and small effect size in other directions were seen, as mentioned above. Therefore, it was considered as the improvement of balance in PM direction in the VR group that lasted until follow-up (Table 5). The CAIT score had a large effect size in both groups (0.91, 0.93 in the control and VR group, respectively). This indicated that the sense of instability reduced in both groups and lasted until follow-up (Table 5). In within-group comparison, for uninvolved limb, there were significant differences in PL and AL directions in both groups and PM and Post directions in the VR group and AL direction in the control group, but the effect size was small (Table 4). Therefore, these improvements were not considered important in the clinic.

Table 1: The mean and Standard Deviations (SD) of demographic characteristics for each group.

Variables	Control Mean (SD)	Virtual Reality Mean (SD)	t	*P*
Age (yr.)	21.78 (2.29)	22.04 (2.10)	-0.433	0.667
Weight (kg)	67.04 (12.03)	66.22 (12.63)	0.243	0.809
Height (m)	1.74 (0.11)	1.75 (0.14)	-0.198	0.844
Duration of physical activity in basketball (yr.)	7.96 (2.36)	7.93 (1.94)	0.063	0.950

t: t-value, *P*: *P*-value

Table 2: The mean and Standard Deviations (SD) of variables for pre-test, post-test and follow-up assessments for involved limb were shown.

Sides	Variables	Pre-test Control N=27 Mean (SD)	Pre-test VR N=27 Mean (SD)	Post-test Control N=27 Mean (SD)	Post-test VR N=27 Mean (SD)	t	*P*	Follow-up Control N=27 Mean (SD)	Follow-up VR N=27 Mean (SD)	t	*P*
Involved limb	Ant.	1.02 (0.14)	1.03 (0.15)	1.02 (0.12)	1.08 (0.14)	-1.825	0.070	1.07 (0.13)	1.08 (0.14)	-0.289	0.774
	AM	0.99 (0.11)	1.07 (0.14)	1.10 (0.12)	1.13 (0.14)	-0.473	0.639	1.09 (0.13)	1.07 (0.14)	0.889	0.378
	Med.	1.06 (0.15)	1.03 (0.14)	1.12 (0.13)	2.46 (7.08)	-0.895	0.375	1.12 (0.14)	1.15 (0.14)	-0.980	0.332
	PM	1.00 (0.14)	1.02 (0.14)	1.11 (0.13)	1.19 (0.16)	-2.166	0.035	1.16 (0.16)	1.19 (0.16)	-0.438	0.663
	Post.	1.01 (0.14)	1.03 (0.14)	1.11 (0.12)	1.19 (0.15)	-2.179	0.034	1.10 (0.14)	1.18 (0.15)	-2.069	0.044
	PL	0.93 (0.12)	0.94 (0.12)	1.03 (0.12)	1.05 (0.13)	-0.425	0.672	1.02 (0.12)	1.04 (0.14)	-0.289	0.774
	Lat.	0.95 (0.11)	0.89 (0.09)	0.96 (0.09)	0.96 (0.10)	-1.505	0.139	0.96 (0.09)	0.96 (0.11)	-1.751	0.086
	AL	0.86 (0.12)	0.85 (0.13)	0.86 (0.12)	0.85 (0.13)	-0.223	0.824	0.86 (0.12)	0.85 (0.13)	0.220	0.827
	CAIT Score	22.37 (0.84)	22.04 (0.98)	26.63 (0.79)	27.26 (0.94)	-2.509	0.015	26.26 (0.71)	27.04 (1.09)	-3.378	0.001

VR: Virtual Reality, SD: Standard Deviations, Ant: Anterior, AM: Anteromedial, Med: Medial, PM: Posteromedial, PL: Posterolateral, Lat: Lateral, AL: Anterolateral, CAIT: Cumberland Ankle Instability Tool, t: t-value, *P*: *P*-value

Table 3: The mean and Standard Deviations (SD) of variables for pre-test, post-test and follow-up assessments for uninvolved limb were shown.

Sides	Variables	Pre-test Control N=27 Mean (SD)	Pre-test VR N=27 Mean (SD)	Post-test Control N=27 Mean (SD)	Post-test VR N=27 Mean (SD)	t	*P*	Follow-up Control N=27 Mean (SD)	Follow-up VR N=27 Mean (SD)	t	*P*
Uninvolved limb	Ant.	0.99 (0.15)	0.99 (0.11)	1.02 (0.17)	1.03 (0.16)	-0.270	0.788	1.01 (0.17)	1.03 (0.16)	-0.378	0.707
	AM	1.01 (0.13)	1.03 (0.10)	1.04 (0.15)	1.07 (0.14)	-0.526	0.601	1.04 (0.15)	1.07 (0.14)	-0.603	0.549
	Med.	1.04 (0.14)	1.17 (0.60)	1.10 (0.15)	1.12 (0.14)	-0.509	0.613	1.09 (0.15)	1.12 (0.15)	-0.592	0.556
	PM	1.09 (0.14)	1.10 (0.13)	1.15 (0.15)	1.17 (0.15)	-0.328	0.744	1.14 (0.15)	1.17 (0.14)	-0.368	0.714
	Post.	1.06 (0.15)	1.07 (0.14)	1.13 (0.16)	1.15 (0.14)	-0.454	0.652	1.12 (0.16)	1.14 (0.15)	-0.426	0.672
	PL	0.99 (0.13)	1.01 (0.11)	1.06 (0.10)	1.08 (0.12)	-0.653	0.516	1.05 (0.10)	1.07 (0.12)	-0.666	0.509
	Lat.	0.93 (0.11)	0.93 (0.10)	0.98 (0.12)	0.98 (0.12)	-0.183	0.855	0.97 (0.12)	0.98 (0.12)	-0.217	0.829
	AL	0.88 (0.14)	0.88 (0.13)	0.89 (0.14)	0.88 (0.13)	-0.088	0.930	0.88 (0.14)	0.88 (0.13)	-0.158	0.875

VR: Virtual Reality, SD: Standard Deviations, Ant: Anterior, AM: Anteromedial, Med: Medial, PM: Posteromedial, PL: Posterolateral, Lat: Lateral, AL: Anterolateral, t: t-value, *P*: *P*-value

Table 4: Repeated measures analysis of variance for within-group differences in each group.

Side	Variables	Control (N=27)				Virtual Reality (N=27)			
		F	*P*	Effect size	Mean square	F	*P*	Effect size	Mean square
Involved limb	Ant.	2.517	0.121	0.09	0.045	2.523	0.124	0.09	0.051
	AM	12.242	0.002	0.32	0.220	3.594	0.068	0.12	0.074
	Med.	3.244	0.083	0.11	0.063	1.007	0.325	0.04	33.796
	PM	18.395	0.000	0.41	0.297	31.984	0.000	0.55	0.505
	Post.	7.711	0.009	0.23	0.135	25.085	0.000	0.49	0.439
	PL	22.417	0.000	0.46	0.174	22.241	0.000	0.46	0.184
	Lat.	0.376	0.549	0.01	0.002	18.704	0.000	0.42	0.081
	AL	9.206	0.005	0.26	0.077	7.501	0.010	0.22	0.075
	CAIT score	254.461	0.000	0.91	175.355	362.461	0.000	0.93	347.623
Uninvolved limb	Ant.	0.520	0.478	0.02	0.015	0.997	0.328	0.04	0.025
	AM	0.829	0.372	0.03	0.014	1.549	0.225	0.06	0.026
	Med.	3.503	0.072	0.12	0.061	0.188	0.669	0.01	0.046
	PM	3.792	0.062	0.13	0.069	4.264	0.048	0.14	0.071
	Post.	3.111	0.088	0.11	0.065	4.590	0.040	0.15	0.092
	PL	5.169	0.031	0.17	0.069	5.995	0.021	0.19	0.086
	Lat.	2.475	0.127	0.09	0.037	3.784	0.062	0.13	0.053
	AL	4.847	0.036	0.16	0.051	6.757	0.015	0.21	0.069

Ant: Anterior, AM: Anteromedial, Med: Medial, PM: Posteromedial, PL: Posterolateral, Lat: Lateral, AL: Anterolateral, CAIT: Cumberland Ankle Instability Tool, F: F-ratio, *P*: *P*-value

Table 5: Bonferroni post hoc test was performed for all time combinations in each group

Side	Variables	Periods	Control			Virtual Reality		
			Mean Difference	*P*	95% Confidence Interval	Mean Difference	*P*	95% Confidence Interval
Involved limb	PM	Pre-post	-0.104	0.009	-0.186_-0.022	-0.172	0.000	-0.249_-0.096
		Pre-follow	-0.157	0.000	-0.236_-0.078	-0.165	0.000	-0.241_-0.089
		Post-follow	-0.053	0.000	-0.080_-0.027	0.008	0.041	0.000_0.015
	CAIT score	Pre-post	-4.259	0.000	-4.908_-3.610	-5.222	0.000	-5.853_-4.591
		Pre-follow	-3.889	0.000	-4.328_-3.450	-5.000	0.000	-5.669_-4.331
		Post-follow	0.370	0.200	-0.866_0.125	0.222	0.249	-0.093_0.538

AM: Anteromedial, CAIT: Cumberland Ankle Instability Tool, *P*: *P*-value

Discussion

Even though the VR group showed significant improvement in the performance in PM and Post directions and also in CAIT score compared to the control group, but the effect sizes were small, therefore, we believe that both protocols of training improved balance in some directions of SEBT and reduced the subjective-sense of instability. Due to the small effect size in some directions in the VR and control group at post-test and follow-up compared pre-test, only the VR group in PM direction with medium effect size had shown improvement of balance. The PM direction of the SEBT was the most important direction for lower limb function compared to other directions in individuals with ankle instability [10]. In this study, both groups showed a significant increase with a large effect size in CAIT score at post-test and follow-up compared pre-test. Accordingly, we suggested that both virtual reality exercises and traditional exercises were effective in improving the stability of the ankle using CAIT as a simple, reliable, and valid tool for classifying individuals with FAI [4, 5].

VR training is described as a type of neuromuscular exercise, a combination of strength and balance training, with feedback [28, 29]. Balance and strength interactions are essential for lower limb function. A study had reported that lower limb function training requires other motor skills such as balance control, bilateral coordination, and lower limb mobility [28]. Also, sufficient strength was required for natural motion patterns [30]. Therefore, a combination of balance and strength training should be considered in ankle instability to enhance the possible results of training and rapid recovery.

The feedback provided in the Wii exercise was very important for motivating the individual and positive reinforcement [14]. This feedback has led to an increase in motor skill learning [31]. It also improved the subject's motor control [32]. Neuromuscular training programs were performed to improve performance, prevent injury, or provide rehabilitation for patients with FAI [33]. McGuine and Keene demonstrated the positive effect of neuromuscular exercises in reducing the rate of sports injuries [34] and improving performance after sports injury [35].

The limitations of the study were as follows: the intervention and follow-up periods were short (i.e. 4 weeks) and only young male basketball players were evaluated. Then our results could not be extended to females and also other ranges of ages, thus, the present training protocols can be implemented in the training of young male basketball players to prevent a recurrence f ankle sprain.

Besides, our research concentrate on ankle balance, therefore, future research should cover other areas such as proprioception and strength in athletes and none athletes.

Conclusion

Although the ankle sprain has been extensively investigated, determining the most effective rehabilitation protocol for treatment is difficult in particular for a recurrent ankle sprain. Our results showed that both training protocols (e.g. VR and conventional exercises) were effective in reducing the subjective sense of instability and improvement of balance in athletes with FAI. Besides, VR training improved balance in PM direction of SEBT after training compared with before training that is the most important direction in FAI. Moreover, VR training was very attractive for the participants.

Acknowledgment

Tehran University of Medical Sciences had financially supported this study. We appreciate all the staff at the School of Rehabilitation.

Authors' Contribution

N. Mohammadi conceived the idea. The paper was written by N. Mohammadi and M. Hadian. The study was designed by N. Mohammad, M. Hadian and Gh. Olyaei. The experiment was carried out by N. Mohammadi. Results and Analysis was carried out by N. Mohammadi. The research work was proofread and supervised by M. Hadian and Gh. Olyaei. All the authors read, modified, and approved the final version of the manuscript.

Ethical Approval

The Ethics Committee of Tehran University of Medical Sciences approved the protocol of the study (Ethic cod: IR.TUMS.FNM.REC.1396.3235).

Informed Consent

The informed consent forms by all athletes signed.

Funding

This study was supported by Tehran University of Medical Sciences [grant number: 260/48].

Conflict of Interest

None

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