Acta of Bioengineering and Biomechanics
Vol. 20, No. 2, 2018

Original paper
DOI: 10.5277/ABB-01101-2018-02

Effect of different balance training programs on postural control in chronic ankle instability: a randomized controlled trial

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Background: Chronic ankle instability (CAI) is a common sequence of ankle sprain. Conservative treatment of CAI is currently accepted as a primary mean of managing the condition and preventing of recurrence. *Objectives*: The purpose of the current study was to evaluate the effect of Weight-bearing Exercise for Better Balance (WEBB) program and unilateral balance training exercises on postural control in females with CAI. *Methods*: Thirty-five females with CAI participated in this study. The participants' mean values of age, body mass, height, and body mass index were 21.76 ± 1.96 y, 64.82 ± 9.37 kg, 161.85 ± 7.24 cm, and 24.76 ± 3.76 kg/m², respectively. They were randomly assigned into three groups: experimental group A (n = 13) who received WEBB program, experimental group B (n = 12) who received unilateral balance training, and control group C (n = 10) using statistical random tables. Balance parameters were measured for all participants via Biodex Balance System (BBS) before and after four weeks of balance training. They included overall stability index (OASI), antero-posterior stability index (APSI), and medio-lateral stability index (MLSI). *Results*: There was a significant improvement in the post testing mean values of OASI and APSI, compared with the pre testing values in both experimental groups (A and B). There was no significant difference between the pre and post testing mean values of MLSI in the experimental group (A). *Conclusions*: Both WEBB program and unilateral balance training have positive effects on postural control in females with CAI.

Key words: *Balance training, Postural control, Chronic ankle instability*

1. Introduction

Ankle joint is the second most common injured body part in sports. Lateral ankle sprains (LAS) are the most common type of ankle injury [7], more common in females than in males, and in children, compared with adolescents and adults. Ankle recurrent injury accounts for 25% of all recurrent injuries [30]. Re-injury of ankle sprain generates chronic ankle instability (CAI), which acts as a cause for recurrent sprains in 55–72% of the cases. Indoor and sports activities were found to be at the highest risk for CAI [3].

Ligament laxity, muscle weakness, proprioception deficits, and postural control deficits result in CAI. Two primary types of CAI are mechanical ankle instability (MAI) and functional ankle instability (FAI). Various insufficiencies that result in each type of instability have been recognized in those with CAI. Functional insufficiencies include impaired proprioception, altered neuromuscular control (NMC), strength deficits, and diminished postural control. Impairments in proprioceptive system and NMC lead to postural control deficits. During single leg balance, the foot pronates and supinates trying to maintain the body's center of gravity (COG) above the base of support (BOS). This is called the ankle strategy of postural control [18].

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Received: January 1st, 2018
Accepted for publication: May 15th, 2018

Individuals with CAI use a hip strategy to maintain unilateral stance more than uninjured individuals. The hip strategy is less efficient than the ankle strategy in maintaining unilateral stance. This, in turn, produces impairments in postural control strategy because of alterations in central neural control in the case of impairment of the ankle joint. Thus, individuals with CAI are unable to maintain stability above a narrow BOS in single-limb stance. Regaining the ankle strategy repositions the COG by moving the whole body as a single segment inverted pendulum via production of torque radiating from distal to proximal body regions. Therefore, restoring the postural control is a key for treatment of CAI [12].

Conservative treatment of CAI is currently considered as the primary method of management and injury prevention. In addition, researchers have reported improvements in NMC and postural stability after rehabilitation of acute LAS and CAI in both limbs. It was concluded that after LAS, the NMC is not only controlled by peripheral mechanoreceptors but also controlled by adaptations in the central pathways [14]. A comparison between the effects of various types of treatments is still largely missing. There is inadequate evidence to select the most effective components of a rehabilitation program. Despite the effectiveness of balance training in improving postural control in LAS, the exact parameters needed to maximize its benefits remain unknown. Most of the previous studies assessed the effect of one program on postural control and few compared the efficacy of different programs. O'Driscoll and Delahunt [25] conducted a systematic review including 14 controlled trials. They reported that these trials examined the efficacy of a specific treatment strategy as balance training or strength training in isolation on sensorimotor function without taking in consideration comparison between treatment programs. Therefore, the purpose of the current study was to compare between the effect of WEBB program and unilateral balance training exercises on postural control in females with CAI.

2. Materials and methods

2.1. Participants

Thirty-five females with CAI were recruited from the Faculty of Physical Therapy, Cairo University by announcements to participate in this study. The participants' mean values of age, body mass, height, and body mass index were 21.76 ± 1.96 y, 64.82 ± 9.37 kg, 161.85 ± 7.24 cm, and 24.76 ± 3.76 kg/m², respectively. They were randomly assigned into three groups; experimental group A (n = 13) performed the WEBB program, experimental group B (n = 12) performed unilateral balance training, and control group C (n = 10) did not receive any treatment. Simple random allocation was done using statistical random tables. There were no significant differences in the mean values of the participants' demographic data including age, body mass, and height among the three tested groups, as shown in Table 1. All subjects read and signed informed consent form before initiation of testing. The study was approved by Research Ethical Committee of Faculty of Physical Therapy, Cairo University (P.T.REC/012/001609).

2.2. Eligibility criteria [8]

Participants were included in the study if they met any of the following criteria:

1) a history of at least one ankle sprain and the initial sprain must have occurred at least 12 months prior to study enrollment,
2) in the case of recurrent ankle sprain, the most recent injury must have occurred more than three months prior to study enrollment (with a history of unassisted walking and no limping for at least three months after injury),
3) a history of giving way of the previously injured ankle joint, and/or feelings of instability,

Table 1: Participants' demographic data

$\bar{X}$ ± SD			
	Experimental group (A)	Experimental group (B)	Control group (C)
Age [years]	21.76 ± 1.96	20.83 ± 1.85	22.40 ± 3.16
Body mass [kg]	62.15 ± 8.97	66.16 ± 11.63	66.70 ± 6.54
Height [cm]	162 ± 8.78	161.16 ± 7.44	162.50 ± 5.14
Pairwise comparisons tests of one way MANOVA			
Experimental (A) *vs.* Control (C)	P = 1.00		
Experimental (B) *vs.* Control (C)	P = 0.381		
Experimental (A) *vs.* Experimental (B)	P = 0.972		

4) the injured/unstable ankle is more painful, looser, and less functional than the uninvolved ankle.

Participants were excluded from the study if they met any of the following criteria:

1) a history of previous surgeries or fractures in any lower extremity,
2) acute injury to musculoskeletal structures of other joints of the lower extremity in the previous three months, which impacted joint integrity and function (sprains, fractures) resulting in at least one interrupted day of desired physical activity,
3) any positive findings in an anterior drawer or talar tilt test,
4) balance deficits due to vestibular disorders, such as vertebro-basilar insufficiency and/or visual disorders.

2.3. Biodex Balance System (BBS)

Balance measures were carried out using the Biodex Balance System (BBS) (Biodex medical systems, Inc. Shirley (NY)). BBS provides valid, reliable and repeatable objective measures of a patient's ability to balance on stable and unstable surfaces. It is used as a dynamic postural control assessment and also a training system. It calculates three separate measures: Medio-Lateral Stability Index (MLSI), Antero-Posterior Stability Index (APSI), and Overall Stability Index (OASI). A high score indicates substantial movement away from the participant's COG, which indicates poor balance. The BBS helps to assess the participant's NMC in a closed chain by measuring the ability of the participant to control dynamic unilateral postural stability on a movable surface [19].

The BBS consists of a mobile balance platform, which gives up to 20° of surface tilt in 360° range and is interfaced with a microprocessor-based actuator. This actuator controlls the degree of surface instability and adjusts the manually preset degree of surface instability, which ranges from a completely stable surface (stability level eight) to a very mobile surface (stability level one). The stability level simply refers to the predetermined stability or firmness of the balance platform. The degree to which the platform tilts during a balance assessment is indicated by the patient's balance ability [26].

During testing, participants were asked to stand on the affected leg on the central region of the platform while the other leg was in a position of slight hip flexion/abduction and 90° of knee flexion. The non-stance leg did not touch the stance leg during the trial. The foot coordinates were recorded for the first time and were maintained throughout the testing trials of each participant. Since balance system provides visual biofeedback of participants' abilities to maintain their COG within their BOS, participants were asked to look straight ahead to get their feedback from the screen. This helped them correct their posture and regain balance by keeping the platform level and by centering the point that represents COG on the screen within BOS borders. Thus, they placed both hands beside the body and tried to keep the platform as motionless as possible holding the cursor inside the inner ring of the screen as much as possible for 20 seconds. Balance testing consisted of three trials and each trial lasted 20 seconds.

When the participant heard the information "the plate is now unlocked", the test started. Once the subject completed the test, the clock stopped and the test trial was ended. The foot platform locked automatically. The results were collected and averaged by the software and displayed on the screen. The Stability Index represented the variance of platform displacement in degrees from a leveled position in both the AP and ML directions. A high number was then indicative of poor NMC, which may increase the risk of injury or falling.

2.4. Training programs

1 – Weight-bearing Exercise for Better Balance (WEBB) program [29]

The WEBB program in the current study was performed three times per week for four weeks [17]. The program consisted of a warm-up exercise, standing with a decreased base exercise, graded reaching in standing, and walking practice. No rest period was given between each trial but a rest period of 10 seconds was given between each exercise.

Warm up exercise was done at the beginning of the program for three minutes by high stepping on a step of 24 cm height. The participants were asked to ascend the step maintaining their static balance for 10 sec, then descend and do the same with the other leg for five repetitions in each limb.

Standing with a decreased base exercise was performed bilaterally with the following graduations 1) feet together and leveled, 2) semi-tandem stance, 3) tandem stance, and 4) single limb stance on the affected leg (Fig. 1). At each graduation, no activity was required to be done except maintaining static balance for one minute [1]. As recommended by Sherrington et al. [29], repetitions increased gradually from 10, 12, 15 to 20 repetitions throughout the four weeks of training [1]. The graduation of exercise was done by increasing the repetitions, from 10 in the first week to 12 in the second week and from 12 in the second week to 15 in the third week and so on, but not by increasing the time of exercise.

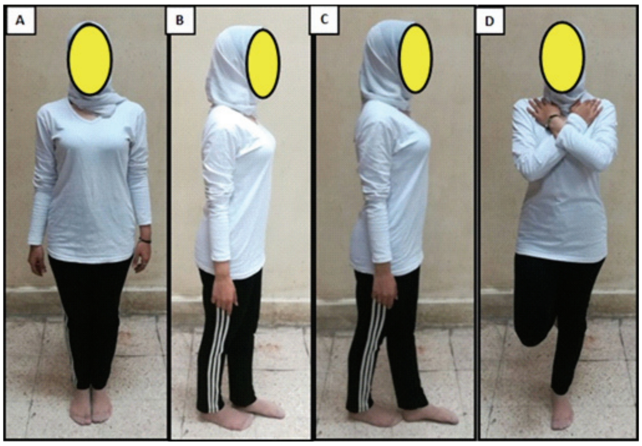

Fig. 1. (A) feet together, (B) semi tandem, (C) tandem stance, and (D) single leg stance on the affected leg

Graded reaching in standing exercise was performed by standing on the affected leg then moving the extended arm in forward, sideward, and backward directions. Each participant was asked to maintain this position for one minute in each direction [1].

Walking practice exercise was done by asking participants to walk 3.5 m stepping over obstacles (cones) of 20 cm height in forward, sideward, and backward directions, initiating the steps and stepping through the cones with the affected leg. The distance between each two successive cones was 50 cm (Fig. 2). Repetitions of this exercise increased gradually from 10, 12, 15 to 20 repetitions throughout the four weeks of training [1].

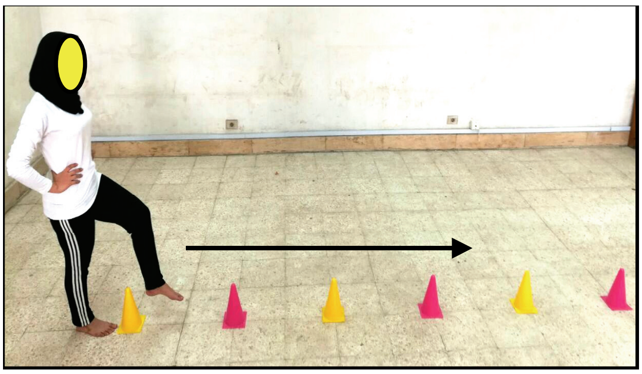

Fig. 2. Walking forward

2 – Unilateral balance training program [10]

This balance training protocol was developed by Hale et al. [10]. The program consisted of single legged stance, wobble board exercises, steamboats, anterior hop, quadrant hop, single-legged ball catch, toe touch down, and hops up and down. It was performed two times per week for four weeks. All exercises were done for the affected limb. Single-legged stance was up to 60 sec per repetition for three repetitions. When participants could complete 60 sec trial without loss of balance, number of repetitions was increased by one in the next weeks. In wobble board exercises, the participant slowly moved the board in plantar flexion, dorsiflexion, inversion, and eversion directions for 10 repetitions in each direction. The board was not allowed to contact the floor (Fig. 3).

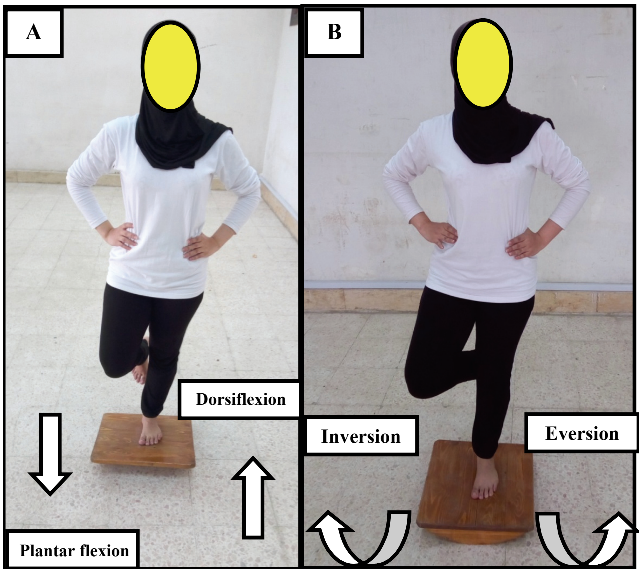

Fig. 3. Wobble board exercise in (A) plantar flexion and dorsiflexion, (B) inversion and eversion

Steamboats exercises were performed with the theraband tied around the unstable ankle and acting as a resistance to the performed movements. The participants were asked to exert their maximal efforts to do hip flexion, extension, abduction, and adduction against the theraband resistance (Fig. 4). Three sets of 10 repetitions were performed in the first two weeks, then progressed to 15 repetitions in the second two weeks. In single-legged hop exercise, the participant hopped as far as comfortable in the anterior direction. It was performed up to 15 repetitions. In quadrant hop, the participant hopped in numbered squares clockwisely and counterclockwisely while maintaining single legged stance (Fig. 5). Two sets of five hops were performed and progressed to unanticipated directions to be enough to stress the participant. In single-legged ball catch, the participant stood on one limb and caught the ball. It was performed up to three sets of 20 tosses. In toe touch down, the participant maintained single-

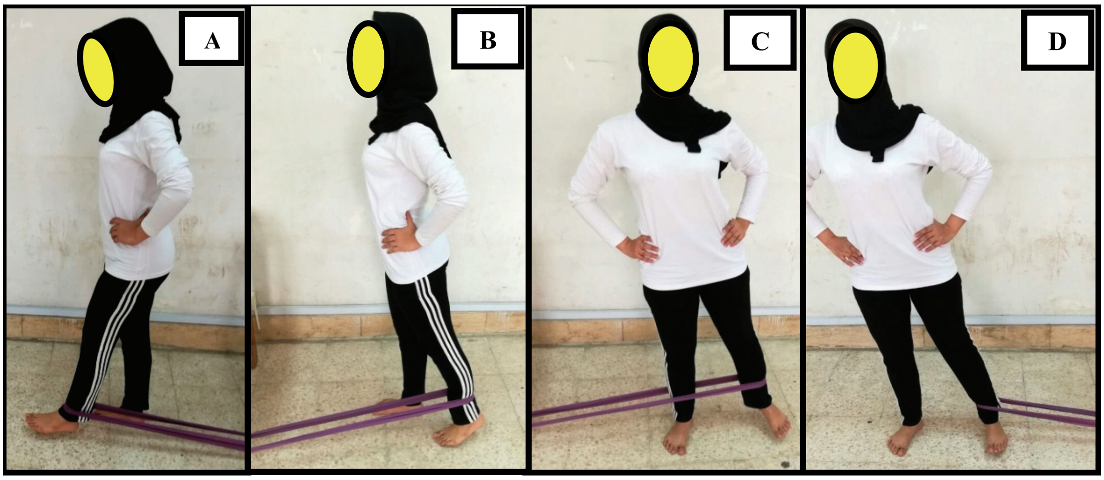

Fig. 4. Steamboats exercise in (A) hip flexion, (B) hip extension, (C) hip abduction, (D) hip adduction

-legged stance on a step of 24 cm height during lowering the stable ankle in anterior, posterior, and lateral directions until the toes contacted the floor. Three sets of 10 repetitions were performed in each direction. In hops up and down, the participant hopped off step (24 cm in height) and landed in single-legged stance on the floor without loss of balance. They did not have to maintain the landing for a period of time. Three sets of 10 repetitions were performed for this exercise.

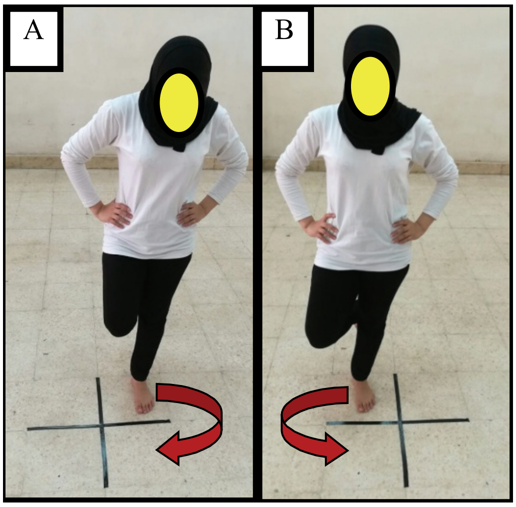

Fig. 5. Quadrant hop (A) clockwise (B) counterclockwise

Regarding the control group, they did not receive any treatment to be able to detect more accurate effect size of the intervention programs among the three tested groups. Any intervention given to the control group would affect the balance results. Furthermore, the main aim of this study was to compare between the WEBB program and unilateral balance training program among the three tested groups rather than comparing them to any other traditional treatment received by the control group. All participants of the control group were checked and followed throughout the four week time frame period of the study. They were instructed not to participate in any physical activities rather than their daily living activities to avoid any misleading improvements minimizing the chance of error and obtaining accurate data in the post-test compared with the pre-test.

2.5. Statistical analysis

Before starting the test procedures, a pilot study was conducted with five participants to determine the appropriate sample size. Power analysis was calculated via power analysis equation at a significance level of 5% and a test power of 80%. The primary outcome measure used in power analysis was overall stability index (OASI). Power analysis revealed that a minimum sample size of 30 participants were required for the study. Since 35 participants were included in the study to randomize the dropouts, statistical analysis using the Statistical Package for Social Sciences (SPSS) revealed a high power of significance of 90% for the study.

3 × 2 mixed design Multivariate Analysis of Variance (MANOVA) was used to assess the effect of two balance training programs on OASI, APSI, and MLSI in females with CAI. The study included two independent variables. The first independent variable was the tested group (between subject factor) with three levels: experimental group (A), experimental group (B), and control group (C). The second independent variable was the testing time (within subject factor) with two levels: pre-testing and post-testing. The three dependent variables were the OASI, APSI, and MLSI.

All statistical measures were performed using SPSS version 20 for Windows. The level of significance for all statistical tests was set at $P < 0.05$.

3. Results

3.1. Flow chart of participants

A total of 38 participants were assessed for eligibility (Fig. 6). Two participants were excluded from the study. One of them did not meet the inclusion criteria and the other declined to participate in the study. Thirty-six participants were then randomized for allocation and subdivided into the three groups: experimental group A (n = 13), experimental group B (n = 13), and the control group C (n = 10). Only one participant in the experimental group (B) dropped out from the study. Data of the thirty-five participants, who completed the study to the end were analyzed.

3.2. Data analysis

The results of 3 × 2 mixed design MANOVA revealed that there was a significant improvement (very large effect size) in the post-testing mean values of OASI (p = 0.001, Cohen's d = 1.7) and APSI (p = 0.000, Cohen's d = 1.7) compared with the pre testing values in the experimental group (A) (Table 2). A significant improvement (very large effect size) in the post testing mean values of all measured variables compared with the pre testing values was observed in the experimental group (B); OASI (p = 0.000, Cohen's d = 2.4), APSI (p = 0.000,

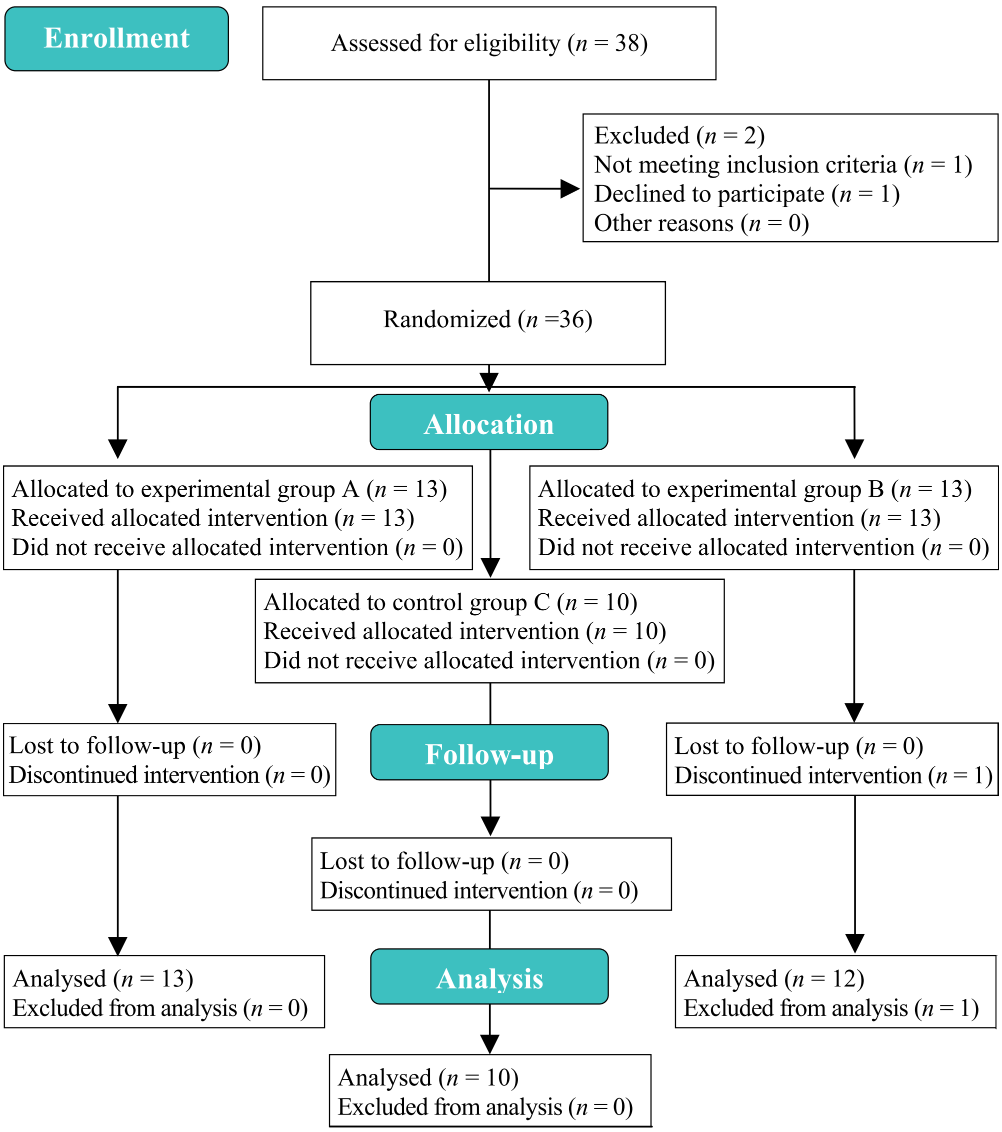

Fig. 6. Flow chart diagram

Table 2. Results of stability indices among the three tested groups

SD ± $\overline{X}$						
Measured variables	Experimental group (A)		Experimental group (B)		Control group (C)	
	Pre	Post	Pre	Post	Pre	Post
OASI	1.90 ± 0.47	1.28 ± 0.22	2.21 ± 0.51	1.25 ± 0.24	2.21 ± 0.43	1.91 ± 0.59
APSI	1.45 ± 0.39	0.89 ± 0.27	1.69 ± 0.33	0.89 ± 0.36	1.58 ± 0.38	1.29 ± 0.35
MLSI	1.21 ± 0.23	1.13 ± 0.28	1.43 ± 0.24	1.01 ± 0.21	1.53 ± 0.45	1.54 ± 0.67
Measured variables	Pre testing *vs*. Post testing (*p* values and effect size estimates)					
	Experimental group (A)		Experimental group (B)		Control group (C)	
OASI	*P* = 0.001* Cohen's *d* = 1.7		*P* = 0.000* Cohen's *d* = 2.4		*P* = 0.121 Cohen's *d* = 0.6	
APSI	*P* = 0.000* Cohen's *d* = 1.7		*P* = 0.000* Cohen's *d* = 2.3		*P* = 0.083 Cohen's *d* = 0.8	
MLSI	*P* = 0.578 Cohen's *d* = 0.3		*P* = 0.006* Cohen's *d* = 1.9		*P* = 0.949 Cohen's *d* = 0.02	
Experimental (A, B) *vs*. Control (C) (*p* values and effect size estimates)						
	OASI		APSI		MLSI	
	Pre	Post	Pre	Post	Pre	Post
Experimental (A) *vs*. Control (C)	*P* = 0.392 Cohen's *d* = 0.7	*P* = 0.001* Cohen's *d* = 1.4	*P* = 1.000 Cohen's *d* = 0.3	*P* = 0.022* Cohen's *d* = 1.3	*P* = 0.060 Cohen's *d* = 0.9	*P* = 0.073 Cohen's *d* = 0.6
Experimental (B) *vs*. Control (C)	*P* = 1.000 Cohen's *d* = 0	*P* = 0.001* Cohen's *d* = 1.5	*P* = 1.000 Cohen's *d* = 0.3	*P* = 0.024* Cohen's *d* = 1.1	*P* = 1.000 Cohen's *d* = 0.3	*P* = 0.015* Cohen's *d* = 1.1
Experimental (A) *vs*. Experimental (B)	*P* = 0.344 Cohen's *d* = 0.6	*P* = 1.000 Cohen's *d* = 0.13	*P* = 0.329 Cohen's *d* = 0.7	*P* = 1.000 Cohen's *d* = 0	*P* = 0.277 Cohen's *d* = 0.9	*P* = 1.000 Cohen's *d* = 0.5

* Significant at alpha level < 0.05.

Cohen's *d* = 2.3), and MLSI (*p* = 0.006, Cohen's *d* = 1.9). Concerning the control group (C), there was no significant difference (medium effect size) in the post-testing mean values of all measured variables compared with the pre testing values; OASI (*p* = 0.121, Cohen's *d* = 0.6), APSI (*p* = 0.083, Cohen's *d* = 0.8), and MLSI (*p* = 0.949, Cohen's *d* = 0.02).

Comparing the results among the three tested groups, it was revealed that there was a significant improvement (very large effect size) in the post-testing mean values of OASI and APSI in the experimental group (A) compared with the control group (C). There was also a significant improvement (medium effect size) in the post-testing mean values of all tested variables in the experimental group (B) compared with the control group (C). There was no significant difference (small effect size) in the post-testing mean values of all measured variables between the two experimental groups (A) and (B) (Table 2).

4. Discussion

Chronic ankle instability results in structural changes of the soft tissues around the ankle due to repetitive ankle sprains and results in impairments in the stability of ankle NMC and musculoskeletal strength [13]. The proprioceptive system deficits result in muscle weakness and postural control impairment after ankle sprain [30]. Quality proprioception is important for improving dynamic joint and functional stability in sports and in daily living activities [22]. Proprioceptive exercises using modalities, such as ankle disks, tilt boards, and single-leg standing activities are effective in minimizing postural sway and improving postural control [6]. Since both WEBB program and unilateral balance training exercises proved their efficacy to enhance balance and coordination in many other musculoskeletal problems including balance deficits, the authors aimed to reveal whether they really have effective role in CAS or not. The authors investigated and compared the effects of two balance training programs on postural control represented by balance indices in females with CAI because CAI is more common in females than in males [30]. Thus the main aim of the study was to provide a variety of balance training programs, which may be beneficial in such cases.

The current study showed a significant improvement in the post testing mean values of OASI and APSI in the WEBB group (A), compared with the pretesting values. Moreover, there was a significant improvement in the post-testing mean values of OASI and APSI in the WEBB group (A), compared with the control group (C).

Very large effect sizes were also detected in OASI and APSI post-testing in the WEBB group (A), compared with the control group (C). Effect sizes, that represent the mean difference divided by standard deviation, enable researchers to move away from the simple identification of statistical significance and toward a more generally interpretable, quantitative description of the size of an effect. This very large size of the effect illustrates the effective role of the WEBB program, which has been developed to target poor balance by improving postural control and minimizing the risk of fall. This, in turn, is the key for treatment of CAI. This program includes high challenge, progressive balance exercises targeting standing balance and walking with progressive moderate-to-high intensity. Furthermore, it reflects the way that the muscles work during daily weight-bearing tasks, such as standing up, walking, reaching, and stair-climbing [4]. It was reported by Sherrington et al. [29] that greater muscle forces and more muscle groups are necessary to gain and maintain the upright posture during weight-bearing exercises. They also concluded that the weight-bearing exercises had a greater effect on the physical outcome measures because of their greater level of difficulty.

Additionally, the WEBB program is a weight-bearing program, which can be considered as a form of closed kinetic chain (CKC) exercises. The CKC exercises involve body movement on a fixed distal segment. This stimulates joint and muscle mechanoreceptors and facilitates co-activation of agonists and antagonists (co-contraction). They also provide greater proprioceptive and kinesthetic feedback than open kinetic chain (OKC) exercises because multiple muscle groups that cross multiple joints are activated. It was found that the CKC exercises are more functional than OKC exercises in improving balance and postural control. Weight bearing on the whole limb stimulates joints' proprioceptors, capsules, tendons of the muscles, and thus helps produce better functional joint stability and postural control. In CKC exercises, a group of muscles and joints works simultaneously, whereas in OKC exercises they work separately. Thus, the effects of CKC exercise are remarkable as the co-contractions and complex actions produced by group of muscles can greatly enhance joint stability. The CKC exercises activate antagonistic muscle groups across multiple joints and therefore cannot be used to isolate or examine a single muscle group. Conversely, OKC exercises isolate specific muscle groups, which is useful for strengthening and evaluation purposes [23].

The WEBB program consists of a warm-up exercise, standing with a decreased base exercise, graded reaching in standing, and walking practice. All these exercises are CKC which improve postural stability. Postural stability is the ability to maintain the COG in a limited spatial zone, which is called the limit of stability. These limitations are not constant, but are related to peripheral situations, body mechanics, and personal activities. It has been recommended that limits of stability are representative of lower extremity function. The postural control system necessitates sensory information integration to estimate the spatial position of the body to develop proper force and adjust the body position. Thus, postural control requires the complex interaction of the neural and musculoskeletal systems [5]. Since WEBB program is a form of CKC exercises, it induces maximal stimulation of joint, muscle and plantar-surface mechanoreceptors of the lower limb [23]. From the above results it is easy to interpret the improvement of postural control which was achieved in this study and confirmed by the ability of participants to control their COG over their BOS during balance testing via BBS.

There was no significant difference in the post testing mean values of MLSI in the experimental group (A), compared with pre-testing values. In the same context, the effect size was small. This reduced effect may be due to the nature of the WEBB program as it does not focus on medio-lateral stability. Only walking sideward in WEBB program challenged medio-lateral stability, unlike unilateral balance training in experimental group (B) which included exercises that targeted both antero-posterior and medio-lateral stability. Steamboat exercises (abduction and adduction of leg against theraband resistance) and wobble board exercise (inversion and inversion) in unilateral balance training program targeted medio-lateral stability while the WEBB program only focused on antero-posterior stability. Exercise frequency differences between the two applied programs could not contribute to the difference in results of MLSI because the other measured indices did not show differences between both programs. Although WEBB program consisted of three exercises and unilateral balance training exercises consisted of eight exercises, both programs gave nearly the same results. This reflects that the WEBB program could achieve more significant effects than unilateral balance training exercises.

Akbari et al. [2] confirmed the insignificant improvement of MLSI in their study. They investigated the effect of a balance training program on balance indices measured by BBS in healthy women. Their program depended on progression from static to dynamic exercises with upper limbs movement and walking practice, like exercises included in the WEBB program of the current study. They revealed improvement in all measured balance indices, except for MLSI. They attributed this insignificant effect to the performed program, which did not focus on medio-lateral stability. They concluded that balance exercise has beneficial effects on all balance indices except MLSI.

Elis and Rosenbaum [6] evaluated the effect of multi-station proprioceptive exercise program in patients with CAI. Subjects of the experimental group reduced postural sway more in the medio-lateral direction. This may be due to the nature of exercises in their study. During the exercises, the position of a slight external rotation of the foot, slightly flexed knee, and the patella in line with the metatarsophalangeal joint in single-limb stance was controlled to force subjects to regulate sway mainly in the subtalar joint. The movement in medio-lateral direction is mainly controlled by the subtalar joint, whereas the movement in antero-posterior direction is more regulated in the tibio-talar joint. From that point of view, the results may be due to the nature of exercises, which focused on the subtalar joint.

Additionally, the current study revealed a significant improvement in the post-testing mean values of all measured variables, compared with the pre-testing values in the experimental group (B). There was a significant improvement in the post-testing mean values of OASI, APSI, and MLSI in the experimental group (B), compared with the control group (C). The effect sizes were very large for all these variables. It can be attributed to the therapeutic effect of unilateral balance training, which was performed by the experimental group (B). It is effective in improving postural control of the trained leg [27]. Contralateral training, also called cross-education or cross-training, help in utilizing motor activity intervention in one limb to produce effective changes in the contralateral limb [20].

Unilateral balance training program performed in the current study consisted of single-legged stance, wobble board, steamboats, single-legged hop, quadrant hop, anterior hop, toe touch down, and hops up and down. Most of these exercises are CKC and include training on unstable surface (wobble board) which forces lower kinetic chain muscles to work harder. Since wobble board training is performed in the weight-bearing position, it is considered a suitable method for reestablishing NMC and improving functional stability of the ankle joint [28].

In addition, there was no significant difference in the post-testing mean values of all measured variables between both tested experimental groups (A and B).The effect sizes were very small in all measured variables. It can be explained that several different rehabilitation techniques are currently being used for CAI and are typically delivered in a multi-station approach which involves several exercises. The WEBB program and unilateral balance training, applied in the current study, are multi-station approaches that focus on static and dynamic postural control, muscle strength, and proprioception of the ankle joint [21].

Multi-station programs are an excellent form of ankle rehabilitation. They not only increase strength and balance of the ankle joint, but also allow for variations to the program which may keep patients motivated [11]. They may improve NMC and postural sway in subjects with CAI [17]. McKeon and Hertel [24] reported that balance training can be used as a preventive method to minimize the initial ankle sprain incidence or as an effective treatment to decrease recurrent ankle sprains. Balance is the highly integrated and dynamic process that requires the interaction of multiple neurological pathways. This helps the body maintain its COG over its BOS [9].

The findings of the current study are supported with that of Rozzi et al. [26], who trained subjects with FAI for four-weeks with the Biodex Stability System. Prior to training, subjects in the functionally unstable group had 27% deficits in single-limb balance ability. Following training, the subjects with the functionally unstable ankle had single-limb balance scores that were almost identical to the post-training scores of the healthy subjects. Although they did not perform the same balance training programs which were conducted in the current study, they reported the same results and concluded that balance training is essential for management of ankle instability. Also, the study conducted by Elis and Rosenbaum [6] supported the findings of the current study. They examined the effects of six-week multi-station proprioceptive exercise program on postural sway and joint position sense. Results revealed significant improvement of postural sway and proprioceptive capabilities. Moreover, Hilgendorf et al. [16] reported large improvements in the OASI outcome in those with CAI after performing four-week balance training program.

The findings obtained by Hale et al. [11] are disagreed with the findings of the current study. They found no significant change in postural control assessed by velocity of center of pressure after four-week rehabilitation program. The inconsistent results may be due to sensitivity of the measures chosen and different tools. Also the training period in that study was only six sessions over four weeks. Moreover, Hertel and Olmsted-Kramer [15] reported that traditional center of pressure measures, such as COPV were not as sensitive to detect CAI related postural control deficits. Complex pathoetiology of CAI must be considered. There are many possible factors contributing to CAI, including weakness, postural-control deficits, impaired proprioception, arthrokinematic changes, ligamentous laxity, and NMC deficits. Classification of individuals with CAI into different groups depends on deficits or treatment response may lead to more systematic management [11].

This study was limited by many factors. Participant dropout was a limitation in this study. This could affect the power of significance of the study. Another limitation was inability to ensure maximum exertion of the participants' efforts during testing and performing some exercises of the intervention programs. During testing, participants were asked to exert their greatest efforts to maintain their COG above their BOS. During treatment, some exercises, such as steamboats exercises of the unilateral balance training program, needed participants to do their best producing motion against the theraband resistance. Furthermore, the authors could not generalize the results beyond the age and gender.

5. Conclusions

From the current study, it was concluded that both WEBB program and unilateral balance training have positive effects on postural control in females with CAI. This, in turn, supports the efficacy of both programs. A clinician could feel confident selecting whichever intervention copes the best with their resources and patient needs.

Acknowledgement

The authors thank all participants in the study for their cooperation.

Conflict of interest

The authors have no conflicts of interest.

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