BACKWARD WALKING VERSUS BALANCE TRAINING IN PATIENTS WITH CHRONIC ANKLE INSTABILITY: A RANDOMIZED CONTROLLED TRIAL

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Abstract

Background: Ankle instability is a common injury, affecting the quality of life, self-reported function, ankle proprioception as well as static and dynamic balance. Purpose: to compare the efficacy of backward walking and Biodex balance training in chronic ankle instability patients. Methods: Sixty subjects participated in this study; their age ranged from 19 to 35 years. They were randomly allocated into three equal groups. Group A received a traditional physical therapy treatment in addition to backward walking training, Group B received a traditional physical therapy treatment in addition to Biodex balance training, and Group C received a traditional physical therapy treatment only (strength training, short foot exercises, heel raise exercises, and calf stretch). All groups received treatment protocols three times a week for 6 consecutive weeks. Outcome measures included the stability indices measured by the Biodex Balance System as well as ankle proprioception measured by a digital goniometer, and functional limitations by the Foot and Ankle Disability Index. Results: Post-treatment Within-Group findings revealed a statistically significant balance improvement by a decrease in the overall, anteroposterior, and medio lateral stability indices, a decrease in ankle proprioception error, as well as a significant increase in Foot and Ankle Disability Index outcomes of all 3 groups ($p < 0.05$). On the other hand, there were no statistically significant differences between groups A, and B related to stability indices, ankle proprioception, and Foot and Ankle Disability Index, while, there were statistically significant differences between groups A and B compared with group C. Conclusion: Backward walking training has a significant effect which appears to be similar to the Biodex balance training in improving balance, risk of fall, ankle proprioception, and decreasing functional limitations in patients with chronic ankle instability.

Keywords: Chronic Ankle Instability**.** Backward Walking Training**.** Biodex Balance**.** Ankle Proprioception**.** Foot and Ankle Disability Index

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Introduction

Lateral ankle sprains are frequently seen in high school, college, and amateur sports, additionally, research suggests that a significant percentage, ranging from 40% to 75%, of individuals affected by these injuries experience ongoing impairment, which may persist for years following the initial sprain [1]. Due to prolonged joint instability and exceeding its natural range of motion, there is an increased risk of damaging the joint's surface and the development of osteoarthritis [2,3]. The injury does not just impact the strength of ligaments but also affects other structures around the joint. Recent ultrasound assessments have revealed a decrease in the cross-sectional area of the peroneus longus muscle in individuals with lateral ankle sprains [4].

The two proposed reasons for Chronic Ankle Instability (CAI) are categorized as mechanical instability and functional instability [5]. Mechanical Instability (MI) is described as ankle movement beyond its normal range. The term 'laxity' is frequently used interchangeably with MI [6].

Functional Ankle Instability (FAI) refers to the sensation of the ankle giving way or feeling unstable following multiple ankle sprains. This condition is believed to result from diminished ankle proprioception, weakened muscles, delayed peroneal reaction time, compromised balance control, sensory-motor dysfunctions, or a combination thereof [1,6].

Changes in sensory information from the somatosensory system near the ankle and central modifications in sensorimotor control after a lateral ankle sprain can cause adjustments in proximal joints to compensate for remaining symptoms and functional limitations [7]. In other words, FAI leads to changes in the activation patterns of the lower limb proximal muscles, which can be seen as notable variations in the amplitude of proximal muscle activity with distal muscle activity during perturbation [8]. Moreover, deficiencies in maintaining balance, stemming from compromised neuro-motor control and proprioception, are frequently observed in individuals with CAI [9], while different balance-training regimes have been shown to enhance balance in CAI patients [10].

Walking is a simple, widely embraced, and budget-friendly exercise option that effectively enhances health and enhances overall well-being [11]. Backward walking is recognized as an effective, non-invasive approach for enhancing muscle function [12]. It leads to increased recruitment of motor units [13], subsequently strengthening the muscles of the lower limbs [12]. Moreover, several studies have indicated that backward walking can enhance balance in various populations, including healthy boys, children with Down syndrome, and individuals with hemiparetic cerebral palsy. [13-15].

The Biodex Balance Training (BBT) system has the potential to enhance the functional capabilities of the neuro-musculoskeletal system by reducing postural misalignment, enhancing spinal kinematics, and improving balance control [16]. There is a debate in the literature about which is more effective BW training or BBT for improving balance, risk of falls, ankle proprioception, and function in CAI patients. So, the current study was conducted to investigate the effect of BW versus Biodex balance training on balance, risk of fall, ankle proprioception, and functional limitations in CAI patients.

Material And Methods

Study design

This study was a randomized controlled trial, with pre and post-test design. It was conducted at the outpatient clinic of the Faculty of Physical Therapy, Cairo University, during the period from November 2022 to June 2023. Prior to initiating the study, ethical approval was obtained from The Research Ethical Committee, Faculty of Physical Therapy, Cairo University, Egypt (P.T. REC/012/003911). The study adopted regulations established by the Helsinki Declaration for human participants. The study protocol was signed up online on Clinicaltrial.gov under the identification number (NCT05585385).

Sample size calculations

The G*POWER statistical software (version 3.1.9.2; Franz Faul, Universität Kiel, Germany) was used to calculate the sample size, utilizing data on OSI obtained from a pilot study involving 5 subjects per group. The analysis indicated that a minimum sample size of N=60 was necessary for this study, with a significance level (α) of 0.05, a power of 80%, and a large effect size of 0.48.

Randomization

Eighty-two subjects with CAI were assessed for eligibility. 22 subjects were eliminated because six were recruited for another study at the same time and 16 did not meet the inclusion requirements. Sixty participants were randomly assigned to three equal groups, labeled as Groups A, B, and C, using a random generator. This allocation process was conducted by an independent individual not involved in participant recruitment or treatment. The random allocation sequence was generated using a computer list by another independent researcher and then sealed in opaque envelopes to maintain allocation concealment. Each eligible participant's envelope was opened prior to their first session. There were no dropouts among the participants following randomization throughout the study (Figure 1).

Participants

Sixty individuals diagnosed with Chronic Ankle Instability (CAI), comprising 33 females and 27 males, were selected from patients attending the outpatient clinic and students at the Faculty of Physical Therapy, Cairo University. Their ages ranged from 19 to 35 years, and their body mass index (BMI) was below 25 kg/m². Inclusion criteria involved obtaining a score of 23 or lower on the Cumberland Ankle Instability Tool (CAIT), indicating severe Functional Ankle Instability (FAI). Participants experienced persistent FAI following the initial lateral ankle sprain, exhibited residual symptoms such as recurrent episodes of ankle instability or giving way, reported recurrent injuries, and demonstrated grade II mechanical ankle instability (identified through manual testing including the talar tilt and anterior drawer tests to assess ankle ligament integrity) [17]. Participants were ineligible for the study if they had experienced grade I or III ankle sprains, deformities of the ankle or foot, swelling of the ankle joint, any rheumatological conditions, prior ankle surgery on either leg, significant restrictions in ankle range of motion, joint diseases or bone fractures, a history of neurological disorders in the lower extremities, flat feet, balance-affecting conditions, or were currently undergoing ankle physical therapy treatment [18].

Group A: (n=20) received a traditional physical therapy treatment (strength training, short foot exercises, heel raise exercises, and calf stretch) in addition to backward walking training, **Group B:** (n=20) received a traditional physical therapy treatment in addition to Biodex balance training.

Group C: (n=20) received a traditional physical therapy treatment only. All groups received treatment protocols three times a week for 6 consecutive weeks (Figure 1).

Instrumentations

Instruments for assessment

Dynamic balance and risk of fall

The Biodex Balance System (BBS), developed by Biodex Medical Systems Inc. in Shirley, NY, USA, is a crucial tool used for both assessing and training individuals with balance impairments [19]. This device is recognized for its reliability and validity in evaluating a participant's capacity to maintain stability in both static and dynamic balance scenarios on its unstable tilting platform. Clinicians utilize the BBS to assess postural control by measuring the individual's ability to maintain stability in dynamic unilateral and bilateral postures on an unstable surface. In the dynamic balance assessment, deviation from the center is gauged by assessing the participant's capability to control the platform's tilt angle [20]. For our study, a dynamic balance test was conducted at stability level six, as determined by a preliminary pilot investigation.

The outcome measures were the overall stability index (OASI), which reflects the participant's ability to maintain balance in all directions; the anteroposterior stability index (APSI), indicating balance maintenance from front to back; and the mediolateral stability index (MLSI), reflecting balance maintenance from side to side. Higher values on these indices indicate greater motion, suggesting a balance issue, whereas lower numerical values indicate less sway and better balance control.

The Biodex Stability System comprises a mobile platform capable of tilting up to twenty degrees in all directions from the horizontal plane. Equipped with a foot grid to ascertain foot positioning prior to testing, the system offers 8

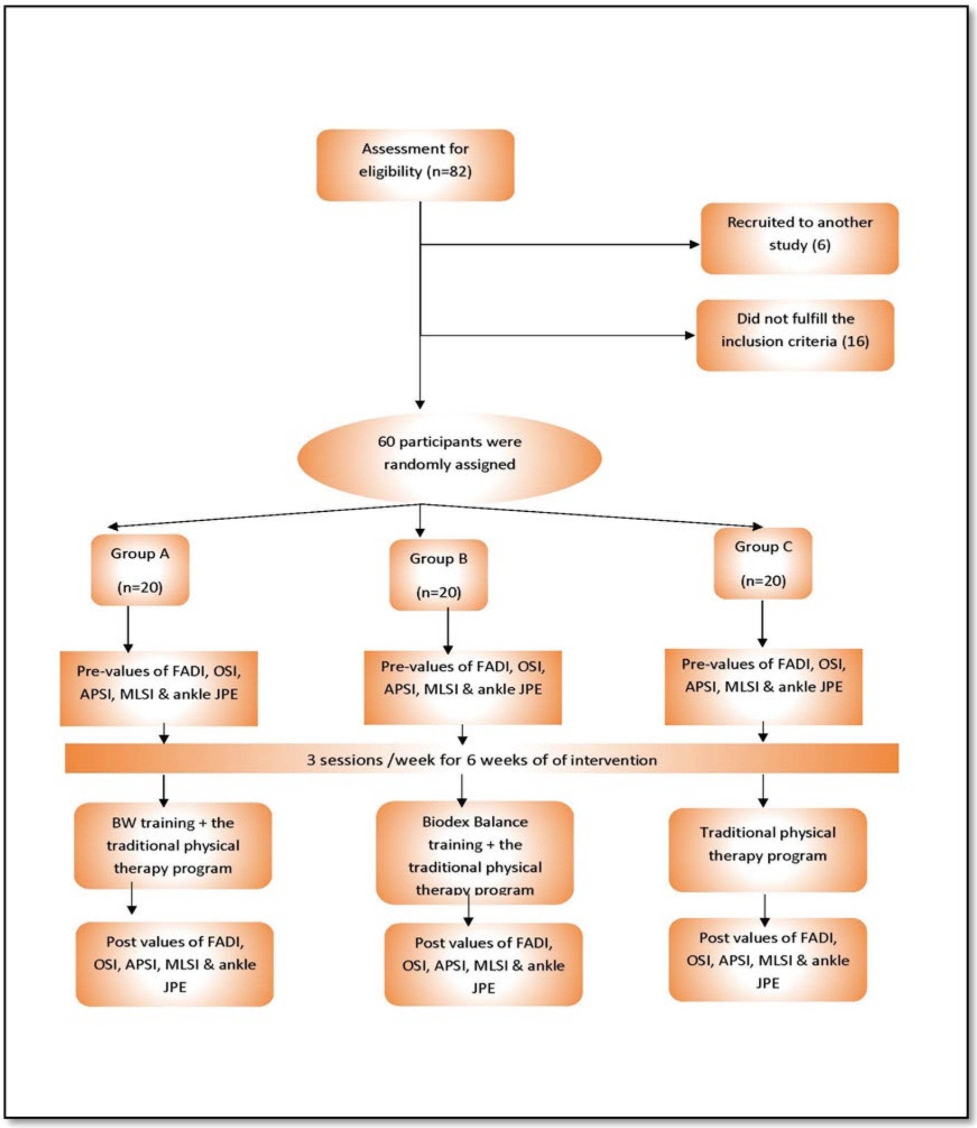

Figure 1. Flow chart of the study participants.

stability levels, with level 8 representing the most stable platform surface and level 1 the most unstable [21]. The risk of falling was solely determined by the actual score on the overall stability index [22].

Ankle Proprioception

Ankle proprioception was assessed (prior to and after completion of 6 consecutive weeks of treatment/ 3 sessions in each week) for all groups by a digital goniometer, which has been proven a valid and reliable method for assessing ankle Joint Position Sense (JPS) and Active Repositioning Accuracy. It demonstrates sufficient concurrent criterion-related validity for assessing joint range of motion (ROM) and exhibits comparable inter- and intra-rater reliability to the Universal goniometer [23].

The assessment of active repositioning accuracy was conducted with participants seated. The digital goniometer's fulcrum was positioned over the distal aspect of the lateral malleolus, with one arm aligned with the head of the fibula and secured using Velcro straps. The movable arm was then aligned parallel to the fifth metatarsal of the foot. Participants were instructed to move only their ankles as directed while keeping the rest of their body still. Prior to commencing the measurements, participants received detailed instructions on the procedure, and a familiarization session ensured proper test execution. The initial position for ankle joint testing was set at 90 degrees.

The maximum ankle plantar flexion for each participant was determined, and half of this maximum range was selected as the target position. Participants were instructed to hold this position for 10 seconds. With eyes closed, they actively moved their ankle from the starting position (90 degrees) to the target plantar-flexion angle at a consistent speed during the test, gradually returning to the initial position and progressing towards the target angle. This procedure was repeated three times, and the average error in actively repositioning to the targeted angle was calculated [24].

Foot and Ankle Disability Index (FADI)

This index comprises 26 items, including 4 related to pain and 22 related to activity. Each question is rated on a 5-point Likert scale ranging from 0 to 4. The total score on the FADI is 104 points, which are then converted into percentages. Studies have shown that both the FADI and FADI Sports versions demonstrate moderate to good reliability in individuals with Chronic Ankle Instability (CAI) [25]. Additionally, FADI has been suggested to possess content validity [26].

Instruments for treatment

Treadmill

The electric treadmill (RAM 770 CE, ITALY) is mainly motor driven, it has a running table with a sliding plate. There is a display screen to choose walking parameters, handrails for support if needed, and a moving belt that moves according to the chosen speed. The running belt is extended between the running deck and the shafts.

Treatment Procedure

Backward walking training

The participant was instructed to walk on a flat treadmill for 30 minutes, with no incline, incorporating warm-up and cool-down periods of 5 minutes each. The walking speed was set to the individual's comfortable pace. Ankle-toe movements, hamstring and calf stretching, and heel raises were performed during the warm-up and cool-down periods. This training regimen was carried out three times a week over six consecutive weeks [27].

Biodex balance training

The participant was directed to stand on the 'locked' platform with both legs. The platform was then adjusted to an unstable state while the participant focused on the visual feedback screen. The arms remained free at the sides of the body without holding onto handrails [16]. Following the selection of the stability training program (dynamic balance training), stability levels were adjusted based on the participant's ability to maintain balance. Participants were instructed to keep their Center of Pressure (COP) within the smallest concentric rings, referred to as the 'A zone,' on the BSS monitor [28].

For the initial two sessions, the platform's stability level was configured at level 8 (the most stable). Subsequently, the stability of the platform was reduced by one level every two sessions to escalate the training difficulty [29]. The Biodex stability program spanned six weeks, with each session lasting 12 minutes and conducted three times a week [28].

Traditional physical therapy exercises

Strength training

It was conducted by utilizing a progressive resistance approach with Thera-Band elasticated bands. Subjects advanced weekly in sets and/or resistance over the training period. During strength training sessions, participants were seated on the floor with knees extended. Thera-Bands, doubled over and attached to a table, were looped around the foot, and subjects performed plantar flexion, dorsiflexion, inversion, and eversion movements. Participants were instructed to focus solely on ankle joint movements, avoiding any additional movements from the knee or hip joints. Training resistance was determined by elongating the bands to 70% of their maximum stretch length. Each subject completed 10 repetitions per set [30,31].

Short foot exercises

The participant was seated on an adjustable chair with the hip and knee joints flexed at 90°, and the foot placed flat on the floor. They were instructed to supinate the foot and bring the first metatarsal head closer to the heel, lifting the medial longitudinal arch without curling the toes to prevent compensation from extrinsic foot muscles. This position was held for 10 seconds before allowing the foot to relax for 1–2 seconds, and then the exercise was repeated 50 times for each foot. Training commenced in a seated position and progressed to a standing position after three weeks, with a total duration of six weeks [32].

Heel raise exercise

The participant was instructed to stand behind a chair for support, placing their hands on the back of the chair. They were then asked to raise their body onto their toes for 5 seconds. Subsequently, they released their hands from the chair and lowered themselves slowly to strengthen the ankle plantar-flexor muscles. This exercise was repeated for 3 sets of 10 repetitions each [33].

Calf stretch

At the end of the exercise program, participants were instructed to perform self-static stretching for the calf muscles. This involved standard gastrocnemius and soleus stretches against a wall, with both the knee straight and bent [34], each held for 15 seconds followed by a 3-second relaxation period. This stretching routine was repeated for 10 repetitions. Stretching the Achilles tendon can aid in preventing hindfoot malpositioning, which increases the susceptibility of lateral ligament injuries [35].

Statistical Analysis

Subject characteristics were compared between groups using a MANOVA test. The Chi-squared test was employed to compare the distribution of sex between groups. The normal distribution of data was assessed using the Shapiro-Wilk test, while Levene's test was utilized to examine the homogeneity of variances between groups. A mixed MANOVA was conducted to analyze both within and between-group effects on stability indices, Joint Position Sense (JPS) error, and Foot and Ankle Disability Index (FADI). Subsequent multiple comparisons were performed using post-hoc tests with Bonferroni correction. The significance level for all statistical analyses was set at $p < 0.05$. Statistical analysis was carried out using the Statistical Package for the Social Sciences (SPSS) version 25 for Windows (IBM SPSS, Chicago, IL, USA).

Results

Subject characteristics

No statistically significant differences were found between groups in baseline demographic characteristics including age, weight, height, BMI, and sex distribution ($p > 0.05$) as shown in (Table 1).

Effect of treatment on stability indices, JPE, and FADI

Mixed MANOVA revealed that there was a significant interaction of treatment and time ($F = 9.35$, $p = 0.001$, Partial Eta Squared = 0.46). There was a significant main effect of time ($F = 376.31$, $p = 0.001$, Partial Eta Squared = 0.97). There was a significant main effect of treatment ($F = 3.84$, $p = 0.04$, Partial Eta Squared = 0.26). Within-group comparison: there was a significant decrease in OSI, APSI, MLSI, and JPS error in the three groups post-treatment compared with that pre- treatment ($p < 0.001$). There was a significant increase in FADI in the three groups post-treatment compared with pre-treatment ($p < 0.001$). (Table 2,3).

Between-group comparisons, there was a significant decrease in OSI, APSI, and MLSI of group A and group B compared with that of group C ($p < 0.001$) while there was no significant difference between group A and B ($p > 0.05$). (Table 2). There was a significant decrease in JPE and a significant increase in FADI of group A and group B compared with that of group C ($p < 0.001$) while there was no significant difference between group A and B ($p > 0.05$). (Table 3).

Discussion

Chronic Ankle Instability (CAI) detrimentally affects balance. This finding is consistent with prior research indicating that balance deficiencies stem from impairments in proprioception and neuromuscular control [36,37].

Table 1. Baseline demographic characteristics of participants.

	Group A	Group B	Group C	p-value
Age, mean ± (SD), years	22.90 ± 2.59	22.25 ± 2.15	21.95 ± 2.52	0.45
Weight, mean ± (SD), years	63.55 ± 6.89	67.80 ± 7.64	66.70 ± 9.62	0.24
Height, mean ± (SD), years	169 ± 7.16	171.75 ± 8.07	170.4 ± 9.20	0.57
BMI, mean ± (SD), kg/m²	22.22 ± 1.74	22.97 ± 1.92	22.87 ± 1.77	0.37
Sex, n (%				
Females	9 (45%)	12 (60%)	12 (60%)	0.54
Males	11 (55%)	8 (40%)	8 (40%)	

SD, standard deviation; p-value, probability value; BMI, Body mass index

Table 2. Mean OSI, APSI, and MLSI pre and post-treatment of groups A, B, and C:

	Group A	Group B	Group C	p-value		
	mean ± SD	mean ± SD	mean ± SD	A vs B	A vs C	B vs C
***OS*I**						
Pre-treatment	5.20 ± 1.55	4.89 ± 1.52	4.82 ± 1.25	0.78	0.69	0.98
Post-treatment	1.60 ± 0.39	1.76 ± 0.54	2.95 ± 0.58	0.57	0.001	0.001
MD (% of change)	3.6 (69.23%)	3.13 (64.01%)	1.87 (38.80%)			
	p = 0.001	***p = 0.001***	***p = 0.001***			
APSI						
Pre-treatment	3.82 ± 0.86	3.76 ± 0.97	3.50 ± 0.64	0.96	0.45	0.6
Post-treatment	1.24 ± 0.34	1.37 ± 0.38	2.55 ± 0.52	0.6	0.001	0.001
MD (% of change)	2.58 (67.54%)	2.39 (63.56%)	0.95 (27.14%)			
	p = 0.001	***p = 0.001***	***p = 0.001***			
MLSI						
Pre-treatment	3.45 ± 1.06	3.41 ± 1.08	3.26 ± 0.88	0.99	0.82	0.88
Post-treatment	1.19 ± 0.35	1.34 ± 0.35	2.14 ± 0.45	0.45	0.001	0.001
MD (% of change)	2.26 (65.51%)	2.07 (60.70%)	1.12 (34.36%)			
	p = 0.001	***p = 0.001***	***p = 0.001***			

SD, standard deviation; p-value, probability value; OSI, Overall stability index; APSI, anteroposterior stability index; MLSI, mediolateral stability index

Table 3. Mean JPS error and FADI pre and post-treatment of groups A, B, and C:

	Group A	Group B	Group C	p-value		
	mean ± SD	mean ± SD	mean ± SD	A vs B	A vs C	B vs C
JPS error (degrees)						
Pre-treatment	8.86 ± 1.47	9.18 ± 1.56	9.29 ± 1.46	0.78	0.63	0.96
Post-treatment	2.09 ± 1.14	2.11 ± 1.06	5.31 ± 1.02	0.99	0.001	0.001
MD (% of change)	6.77 (76.41%)	7.07 (77.02%)	3.98 (42.84%)			
	p = 0.001	***p = 0.001***	***p = 0.001***			
FADI (%)						
Pre-treatment	77.59 ± 5.77	75.86 ± 5.44	76.24 ± 5.36	0.58	0.72	0.97
Post-treatment	96.39 ± 2.89	96.34 ± 2.63	87.11 ± 2.90	0.99	0.001	0.001
MD (% of change)	-18.8 (24.33%)	-20.48 (27%)	-10.87 (14.26%)			
	p = 0.001	***p = 0.001***	***p = 0.001***			

SD, standard deviation; p-value, probability value; JPS, joint position sense; FADI, foot and ankle disability index.

The reduced balance observed in all participants during the pre-treatment assessment correlated directly with the diagnosis of CAI, suggesting that ankle instability contributes to proprioception deficits and disrupts balance by increasing body sway [38]. Furthermore, limitations in ankle dorsiflexion range of motion (ROM) resulting from instability could potentially impact dynamic balance in individuals with CAI [39].

The results of the study revealed that there was a significant decrease in OSI, APSI, MLSI, and JPS error, and a significant increase in Foot and Ankle Disability Index (FADI) score in the three groups post-treatment compared with pre-treatment. There was a significant decrease in OSI, APSI, and MLSI of group A and group B compared with group C, while there was no statistically significant difference between groups A and B. There was a significant decrease in JPS error and a significant increase in FADI of group A and group B compared with group C, while there was no statistically significant difference between groups A and B.

Regarding Backward walking (BW) training, there was a significant post-treatment decrease in the OSI, APSI, and MLSI & a significant decrease in ankle proprioception error in group A compared with group C. The significant improvement in balance and proprioception in this group can be explained on the basis that three main systems contribute to the balance process: (1) the sensory system, encompassing visual, cutaneous, proprioceptive, and vestibular senses, (2) the motor system, and (3) the biomechanical or musculoskeletal system. All three systems play a role in enhancing balance through body weight (BW) training [13,40].

As regards to biomechanical or musculoskeletal system, this improvement in balance is supported by the rationale that in BW training, the toes make contact first and the movement ends with the heel, resulting in an atypical and unfamiliar pattern for the individual. As a result, the subject pays closer attention and becomes more cautious due to the sensation of instability, leading to increased activity in the motor cortex to produce such control and promote postural stability [41,42].

As regards proprioceptive input, the lack of visual cues regarding the direction of walking necessitates the engagement of additional stabilizing mechanisms. These mechanisms may involve other sensorimotor systems, such as proprioception and muscle strength, to compensate for the absence of visual feedback and uphold dynamic balance [43], and the muscle strength change at lower limbs, induced by BW exercise, plays a significant contribution in preserving balance [44], which may be also another plausible explanation. Additionally, as regards the vestibular system, it is obvious that BW training may improve the vestibular system which may be another possible explanation; when walking backward the visual sensation is distorted and the individual uses the vestibular input to compensate for the deficiency in other balance-maintaining systems, in line with the sensory re-weighting theory. [45,46]. Moreover, BW increases neuromuscular control, proprioception [47], and ankle muscles strength [48,49], which improve foot function and mitigate foot pain [50].

Furthermore, the ankle proprioception improvement, in favor of the BW training group, can be attributed to the effect of BW training added to the traditional physical therapy exercises since BW exercise represents a type of closed kinetic chain exercise, where closed chain exercises activate proprioceptors. These receptors gradually adapt during rehabilitation and persist in sending signals to the central nervous system (CNS), as long as the neurological stimulus is sustained, thereby augmenting proprioceptive input [47]. In addition to the improvement of proprioception, the increased dorsiflexors muscle strength plays an important component for maintaining static balance [51]. According to Hoogkamer et al. [52], significant crossed reactions were noted in the anterior tibialis muscle, which played a role in stabilizing and maintaining balance during BW exercises.

Concerning dynamic balance, the findings of this study align with numerous other studies demonstrating a notably greater enhancement in balance and sensorimotor function among patients with various diseases and disorders who underwent treadmill training with a BW program alongside conventional rehabilitation, compared to those who received conventional rehabilitation alone [13,14,40,42,53].

Regarding Biodex balance training (BBT), Likewise, the enhancement in mean values of stability indices (OASI, APSI, and MLSI) observed in the BBT group could be attributed to the classification of BBT as a type of closed kinetic chain exercises. Such exercises stimulate muscle and joint mechanoreceptors and promote co-contraction of agonist and antagonist muscles, aiding in the restoration of balance, postural control, and improved functional joint stability [54,55].

The human postural system relies on integrated information from somatosensory, vestibular, and visual inputs. During tasks like BBT, this information is continuously adjusted to effectively control and sustain balance across various situations by re-evaluating body forces and generating appropriate responses [29]. BBT also may serve to improve neural output in response to postural disturbances by the contribution of several factors including strength training, balance training, dynamic performance training, and the application of compressive loading on the joint. These elements collectively enhance functional performance by improving both static and dynamic balance, thus contributing to overall dynamic balance, functional instability improvement, and the ROF decrease [28]. These results are also similar to the findings of Anguish and Sandrey [56] who stated that a four-week dynamic balance training program can increase self-reported function in Foot and Ankle Ability Measures (FAAM) in CAI patients.

The results of the current study also showed a significant decrease in post-treatment mean values of OASI, APSI, MLSI, and JPS error, and a significant increase in FADI score in group C which received the traditional physical therapy program only. The present results were consistent with other studies such as Donovan et al. [57] showing that a supervised rehabilitation program lasting 4 weeks, which included functional exercises, ROM exercises, strength training, and balance exercises, resulted in significant improvements in self-reported function, dynamic balance, and ankle strength. Furthermore, these results agreed also with Lee et al. [32] who confirmed that SFE training leads to significant enhancements in proprioception and balance among patients diagnosed with CAI when compared with proprioceptive sensory exercises (PSE). Moreover, the results may agree with the explanation given by Kim and Kim [58]; motor training transmits proprioceptive sensory signals to the sensory cortex region of the brain, influencing the motor area as well. This process helps correct asymmetric muscle tone in the sole and prompts the development of appropriate new movements, thereby enhancing motor sensation and addressing postural disturbances to promote the maintenance of body balance and stability.

On the other side, the findings of this study did not agree with the study of Hall and Docherty [59] who stated that strength training protocols do not improve balance in participants with CAI, however, this may be because authors have used strength training only in their study rather than the other conventional exercises that have been used in the current study in addition to the strengthening protocol.

Limitations Of The Study

The study was limited to adult non-athletic participants, omitting consideration of various age groups or athletic populations. Additionally, the treatment duration was relatively short, spanning only 6 weeks. Furthermore, long-term impacts or follow-up assessments were not explored. Therefore, further research is warranted to assess the enduring effects of the treatment protocol with an extended follow-up period. Future studies should encompass diverse age groups and include athletes to uncover potential differences in outcomes.

Conclusion

Both BW training and BBT demonstrate clear therapeutic benefits in enhancing balance, reducing the risk of falls, improving ankle proprioception, and enhancing ankle function in patients with CAI. However, no significant difference was found between BW and BBT in the rehabilitation of individuals with CAI.

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Conflict of Interests

The authors declare no conflict of interest.

References

1. Lee, A.J. and W.H. Lin. Twelve-week biomechanical ankle platform system training on postural stability and ankle proprioception in subjects with unilateral functional ankle instability. Clin. Biomech 2008;23: 1065-1072.
2. Willems, T., E. Witurouw, J. Verstuyft, P. Vaes and D. De Clercq. Proprioception and muscle strength in subjects with a history of ankle sprains and chronic instability. J. Athl. Train 2002;37: 487-493.
3. Hintermann, B., A. Boss and D. Schafer. Arthroscopic findings in patients with chronic ankle instability. Am. J. Sports Med 2002;30: 402-409.
4. Lobo CC, Morales CR, Sanz DR, Corbalán IS, Marín AG,López DL. Ultrasonography comparison of peroneus muscle cross-sectional area in subjects with or without lateral ankle sprains. J Manipulative Physiol Ther 2016;39: 635-44.
5. Tropp, H. Commentary: Functional ankle instability revisited. J. Athlet. Train 2002;37: 512-515.
6. Hertel, J. Sensorimotor deficits with ankle sprains and chronic ankle instability. Clin. Sports Med 2008;27: 353-370.
7. Terada, M., B.G. Pietrosimone and P.A. Gribble. Alterations in neuromuscular control at the knee in individuals with chronic ankle instability. J. Athlet. Train 2014;49: 599-607.
8. Kazemi K, Arab AM, Abdollahi I, López-López D, Calvo-Lobo C. Electromiography comparison of distal and proximal lower limb muscle activity patterns during external perturbation in subjects with and without functional ankle instability. Hum Mov Sci 2017;55: 211-20.
9. Coughlan G, Caulfield B. A 4-week neuromuscular training program and gait patterns at the ankle joint. J Athl Train 2007;42: 51-9.
10. Hale SA, Hertel J, Olmsted-Kramer LC. The effect of a 4-week comprehensive rehabilitation program on postural control and lower extremity function in individuals with chronic ankle instability. J Orthop Sport Phys Ther 2007;37: 303-11.
11. Ogilvie D, Foster CE, Rothnie H, Cavill N, Hamilton V, Fitzsimons CF, et al. Interventions to promote walking: systematic review. BMJ. 2007;334(7605):1204; doi: 10.1136/bmj.39198.722720.BE.
12. Zhang X, Zhang Y, Gao X, Wu J, Jiao X, Zhao J, et al. Investigating the role of backward walking therapy in alleviating plantar pressure of patients with diabetic peripheral neuropathy. Arch Phys Med Rehabil. 2014;95(5):832–839; doi: 10.1016/j.apmr.2014.01.003.
13. El-Basatiny HMY, Abdel-Aziem AA. Effect of backward walking training on postural balance in children with hemiparetic cerebral palsy: a randomized controlled study. Clin Rehabil. 2015;29(5):457–467; doi: 10.1177/026921 5514547654.
14. Hao W-Y, Chen Y. Backward walking training improves balance in school-aged boys. Sports Med Arthosc Rehabil Ther Technol. 2011;3:24; doi: 10.1186/1758- 2555-3-24.
15. Yang Y-R, Yen J-G, Wang R-Y, Yen L-L, Lieu F-K. Gait outcomes after additional backward walking training in patients with stroke: a randomized controlled trial. Clin Rehabil. 2005;19(3):264–273; doi: 10.1191/02692155 05cr860oa.

16. El-Gohary TM, Emara HA, Al-Shenqiti A, Hegazy FA. Biodex balance training versus conventional balance training for children with spastic diplegia. J Taibah Univ Med Sci 2017;12: 534-40.

17. Delahunt E, Coughlan GF, Caulfield B, Nightingale EJ, Lin CWC, Hiller CE. Inclusion criteria when investigating insufficiencies in chronic ankle instability. Med Sci Sports Exerc 2010;42: 2106-21.

18. Ali, O.I. and S.A. Alasar. Assessment of lumbar proprioception in participants with functional ankle instability: A cross-sectional study. Bull. Facul. Phys. Ther. 2016;21: 74-79.

19. El-Shamy SM, Abd El Kafy EM. Effect of balance training on postural balance control and risk of fall in children with diplegic cerebral palsy. Disabil Rehabil 2014;36: 1176-83.

20. Arifin N, Osman NAA, Abas WABW. Intrarater test-retest reliability of static and dynamic stability indexes measurement using the Biodex Stability System during unilateral stance. J Appl Biomech 2014;30: 300-4.

21. Brown, S. R., Brughelli, M., & Lenetsky, S. Profiling Single-Leg Balance By Leg Preference And Position In Rugby Union Athletes. Motor Control 2018; 22(2), 183-198.

22. Khalaj, N., Abu Osman, N. A., Mokhtar, A. H., Mehdikhani, M., & Wan Abas, W. A. B. Balance and Risk of Fall in Individuals with Bilateral Mild and Moderate Knee Osteoarthritis. PLoS ONE 2014;9(3), e92270. doi:10.1371/journal.pone.0092270

23. Carey, M., Laird, D., Murray, K.A., & Stevenson, J.R. Reliability, validity, and clinical usability of a digital goniometer. Work 2010;36 1, 55-66.

24. Hosseinefar M., Ebrahimi E. and Salavati M. The Relationship Between Ankle Joint Range of Motion and Position Sense in 18-50 Years Old Healthy Subjects in Zahedan. Journal of Medical Sciences 2006;6: 670-673.

25. Hale S. and Hertel J.: Reliability and sensitivity of the foot and ankle disability index in subjects with chronic ankle instability. J Athl Train.2005; 40(1):35-40.

26. Eechaute., Sheri A., Hale. and Hertel J.: The clinimetric qualities of patient-assessed instruments for measuring chronic ankle instability: A systematic review. BMC Musculoskeletal Disorders 2007;8:6 doi:10.1186/1471-2474-8-6.

27. Alghadir AH, Anwer S, Sarkar B, Paul AK, Anwar D. Effect of 6-week retro or forward walking program on pain, functional disability, quadriceps muscle strength, and performance in individuals with knee osteoarthritis: a randomized controlled trial (retro-walking trial). BMC Musculoskelet Disord. 2019;20(1):159; doi: 10.1186/ s12891-019-2537-9.

28. Akhbari, B., Ebrahimi Takamjani, I., Salavati, M., & Ali Sanjari, M. A 4-week biodex stability exercise program improved ankle musculature onset, peak latency and balance measures in functionally unstable ankles. Physical Therapy in Sport 2007;8(3), 117–129. doi:10.1016/j.ptsp.2007.03.004

29. Ibrahim, M. G., Kamel, R. M., Draz, A. H., & Shafie, A. S. Whole body vibration versus biodex balance training in patients with chronic ankle instability: A randomized controlled trial. JCR 2020;7(6),1380-1386.

30. Docherty CL, Moore JH, Arnold BL. Effects of strength training on strength development and joint position sense in functionally unstable ankles. J Athl Train 1998; 33: 310-14.

31. Kaminski TW, Buckley BD, Powers ME, et al. Effect of strength and proprioception training on eversion to inversion strength ratios in subjects with unilateral functional ankle instability. Br J Sports Med 2003; 37: 410-5.

32. Lee E., Cho J. and Lee S.: Short-foot exercise enhances of quantitative somatosensory function. Med Sci Monit, 2019; 25: 618-626.

33. Schoenfelder, D. P., & Rubenstein, L. M. An exercise program to improve fall-related outcomes in elderly nursing home residents. Applied Nursing Research 2004;17(1), 21-31.

34. Loudon JK, Dolphino MR. Use of foot orthoses and calf stretching for individuals with medial tibial stress syndrome. Foot Ankle Spec. 2010;3(1):15–20; doi: 10.1177/1938640009355659.

35. Clanton TO. Instability of the subtalar joint. Orthop Clin North Am 1989;20:583–92.

36. Hertel J. Functional anatomy, pathomechanics, and pathophysiology of lateral ankle instability. J Athl Train 2002; 37: 364.

37. Terada M, Bowker S, Thomas AC, et al. Alterations in stride-to-stride variability during walking in individuals with chronic ankle instability. Hum Mov Sci 2015; 40:154-62.

38. Garn SN, Newton RA. Kinesthetic awareness in subjects with multiple ankle sprains. Phys Ther 1988; 68: 1667-71.

39. Hoch MC, Staton GS, McKeon JMM, Mattacola CG, McKeon PO. Dorsiflexion and dynamic postural control deficits are present in those with chronic ankle instability. J Sci Med Sport 2012;15: 574-9.

40. Abdou, R., El-Negamy, E., & Hendawy, A. Impact of backward gait training on mediolateral stability index in children with hemiparesis. Journal of Medical Science and Clinical Research 2014;2(8), 2042-2049.

41. Zelenin, P. V., Deliagina, T. G., Orlovsky, G. N., Karayannidou, A., Stout, E. E., Sirota, M. G., & Beloozerova, I. N. Activity of motor cortex neurons during backward locomotion. Journal of Neurophysiology 2011;105(6), 2698-2714.

42. Amini, H. A., Fazel Kalkhoran, J., Salehi, M., & Jazini, F. Effect of backward walking training on improves postural stability in children with down syndrome. International Journal of Pediatrics 2016;4(7), 2171-2181.

43. Winter, D. A., Pluck, N., & Yang, J. F. Backward walking: a simple reversal of forward walking?. Journal of Motor Behavior 1989;21(3), 291-305.

44. Boyas, S., Remaud, A., Bisson, E. J., Cadieux, S., Morel, B., & Bilodeau, M. Impairment in postural control is greater when ankle plantarflexors and dorsiflexors are fatigued simultaneously than when fatigued separately. Gait & posture 2011;34(2), 254-259.

45. Pirouzi, S., Motealleh, A. R., Fallahzadeh, F., & Fallahzadeh, M. A. Effectiveness of treadmill training on balance control in elderly people: a randomized controlled clinical trial. Iranian Journal of Medical Sciences 2014;39(6), 565.

46. Wajda, D. A., Sandroff, B. M., Pula, J. H., Motl, R. W., & Sosnoff, J. J. Effects of walking direction and cognitive challenges on gait in persons with multiple sclerosis. Multiple Sclerosis International, vol. 2013, Article ID 859323; 6 pages.

47. Khadilkar, B., & Bedekar, N. The effectiveness of backward walking post anterior cruciate ligament reconstruction results of a randomised controlled trial. Journal of Orthopedic Rehabilitation 2011;1, 23-28.

48. Kachanathu, S. J., Hafez, A. R., & Zakaria, A. R. Efficacy of backward versus forward walking on hamstring strain rehabilitation. International Journal of Therapies and Rehabilitation Research 2013;2(1), 8; doi: 10.5455/ijtrr.00000017.

49. Kim, Y. J., Jang, H. I., Ko, K. H., Chang, W. N., & Lim, S. K. Effect of backward walking training on dynamic balance in children with spastic hemiplegic cerebral palsy. Age 2017;6, 2-18.

50. Panichawit, C., Bovonsunthonchai, S., Vachalathiti, R., &Limpasutirachata, K. Effects of Foot Muscles Training on Plantar Pressure Distribution during Gait, Foot Muscle Strength, and Foot Function in Persons with Flexible Flatfoot. Journal of the Medical Association of Thailand= Chotmaihet Thangphaet 2015;98, S12-7.

51. Singh, S., & Multani, N. K. Effect of dorsiflexor muscle strengthening using Russian currents on balance and function in elderly. Human Biology Review 2013;2(2), 176-184.

52. Hoogkamer, W., Massaad, F., Jansen, K., Bruijn, S. M., & Duysens, J. Selective bilateral activation of leg muscles after cutaneous nerve stimulation during backward walking. Journal of Neurophysiology 2012; 108(7), 1933-1941.

53. Weng, C. S., Wang, J., Pan, X. Y., Yu, Z. Z., Wang, G., & et al. Effectiveness of backward walking treadmill training in lower extremity function after stroke. Zhonghua yi xue za zhi 2006;86(37), 2635-2638.

54. Hall EA, Chomistek AK, Kingma JJ, Docherty CL. Balanceand strength-training protocols to improve chronic ankle instability deficits, part I: assessing clinical outcome measures. J Athl Train 2018; 53: 568-77.

55. Manzoor S, Afzal F, Gulraiz Q, Khalid M. Effects of joints weight bearing exercises combine with range of motion exercises on affected limbs in patents with stroke. Int J Phys Med Rehabil 2017; 5: 410.

56. Anguish B, Sandrey MA. Two 4-week balance-training programs for chronic ankle instability. J Athl Train 2018;53: 662-71.

57. Donovan L.; Hart J.; Saliba s.; Park J.; Feger M.; Herb C. & Hertel J. Rehabilitation for Chronic Ankle Instability With or Without Destabilization Devices: A Randomized Controlled Trial. J Athl Train 1 March 2016; 51 (3): 233–251.

58. Kim, E. K., & Kim, J. S. The effects of short foot exercises and arch support insoles on improvement in the medial longitudinal arch and dynamic balance of flexible flatfoot patients. Journal of physical therapy science 2016; 28(11), 3136-3139.

59. Hall EA. and Docherty CL. Strength-Training Protocols to Improve Deficits in Participants With Chronic Ankle Instability: A Randomized Controlled Trial. J Athl Train 2015; 50 (1): 36–44.