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Balance Training for Persons With Functionally Unstable Ankles

Susan L. Rozzi, PhD, ATC[1]
Scott M. Lephart, PhD, ATC[2]
Rob Sterner, MS, ATC[3]
Lori Kuligowski, MS, ATC[4]

Study Design: A nonrandomized 2-group pretest-posttest design.
Objectives: To determine the effects of a 4-week balance training program during stance on a single leg.
Background: Individuals who have experienced multiple episodes of inversion ankle sprains often participate in balance training programs. Balance training is performed to treat existing proprioceptive deficits and to restore ankle joint stability, presumably by retraining altered afferent neuromuscular pathways. The effectiveness of such programs on individuals with functionally unstable ankles has yet to be established.
Methods and Measures: Prior to and following training, subjects with self-reported functionally unstable ankles (5 women and 8 men, mean age = 21.9 ± 3.1 years) and nonimpaired subjects (6 women and 7 men, mean age = 21.2 ± 2.5 years) completed a static balance assessment for both limbs as well as the ankle joint functional assessment tool questionnaire (AJFAT). The subjects from both groups participated in a unilateral, multilevel, static and dynamic balance training program 3 times a week for 4 weeks. Subjects from the experimental group trained only the involved limb, and the nonimpaired group trained a randomly selected limb. A stability index (SI) was calculated during the balance assessment to indicate the amount of platform motion. Compared to low stability indices, high stability indices indicate greater platform motion during stance and therefore less stability.
Results: Following training, subjects from both groups demonstrated significant improvements in balance ability. When balance was assessed at a low resistance to platform tilt (stability level 2), the posttraining scores of both the subjects with unstable ankles (mean SI = 2.63 ± 1.92) and the nonimpaired subjects (mean SI = 2.69 ± 2.32) were significantly better than their pretraining scores (mean SIs = 5.93 ± 3.65 and 4.67 ± 3.43, respectively). Assessed at a high resistance to platform tilt (stability level 6), the posttraining scores of both subjects with unstable ankles (mean SI = 1.27 ± 0.66) and the nonimpaired subjects (mean SI = 1.37 ± 0.66) were significantly better than their pretraining scores (mean SIs = 2.30 ± 1.88 and 2.04 ± 1.43, respectively). Additionally, the posttraining AJFAT scores of subjects with unstable ankles (25.78 ± 3.80) and the nonimpaired subjects (29.15 ± 5.27) were significantly greater than their pretraining scores (17.11 ± 3.44 and 22.92 ± 5.22, respectively), indicating an overall improvement in perceived ankle joint functional stability.
Conclusions: This study suggests that balance training is an effective means of improving joint proprioception and single-leg standing ability in subjects with unstable and nonimpaired ankles.
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Key Words: *neuromuscular, proprioception, rehabilitation*

[1] *Coordinator of Athletic Training Education, College of Charleston, Charleston, SC.*
[2] *Director, Neuromuscular and Sports Medicine Research Laboratory, Musculoskeletal Research Center, Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.*
[3] *ATC, University of Pittsburgh, Pittsburgh, Pa.*
[4] *University of Pittsburgh, Pittsburgh, Pa.*
Send correspondence to Susan L. Rozzi, College of Charleston, 66 George Street, Charleston, SC 29424. E-mail: rozzis@cofc.edu

Individuals who have experienced multiple episodes of inversion ankle sprains have a condition that may be characterized as a functionally unstable ankle. Functional instability of the ankle joint has been defined by Freeman[7] as "a tendency for the foot to give way after an ankle sprain." Three factors thought to cause functional instability of the ankle joint are anatomic or mechanical instability, muscle weakness, and deficits in joint proprioception.[19] At this time, there are no objective data that conclusively show that muscle weakness is a viable explanation for functional ankle instability. However, the combination of mechanical instability and decreased neuromuscular control resulting from deficits in joint proprioception may result in functional instability of the ankle joint.[8,10,18,19]

Deficits in ankle joint proprioception with diminished neuromuscular control have been documented following ankle joint ligamentous trauma.[4,24] Cornwall[4] demonstrated that individuals with a history of inversion ankle sprains demonstrate less stability when performing a single-leg stance than do nonimpaired subjects. In addition, it has been shown that subjects with an unstable ankle demonstrate a longer reaction time to a sudden angular displacement when compared with nonimpaired subjects.[3,17,24] These neuromuscular deficits, seen as impaired balance ability and increased muscle reaction time, may predispose individuals to repetitive trauma and exacerbation of ankle instability.

Rehabilitation programs that address existing neurological deficits by improving joint proprioception have been recommended for individuals with unstable ankles.[8,11,18,20–22] The sensation of joint movement may be enhanced by improved mechanoreceptor function, which may lead to the restoration of neuromuscular control of the joint. This restoration of the neuromuscular feedback loop may be a key factor that determines a positive outcome (ie, returning to more stable or preinjury levels).[14,16,18,19]

Often, proprioceptive rehabilitation programs prescribe balance training devices, such as unstable balance platforms, in order to address proprioceptive deficits and restore functional stability of the ankle joint.[18,19,30,31] Since balance training is performed in the weight-bearing position, it may be considered an appropriate method of reestablishing neuromuscular control and therefore improving functional stability.[27]

Although the effectiveness of training on an unstable balance platform in nonimpaired individuals has been investigated and documented by various researchers, the effectiveness of such programs has yet to be established in individuals with functionally unstable ankles.[2,5,6,9,12,13,15] Therefore, our study was designed to determine the effects of a 4-week-long single-leg balance training program on the balance of subjects with a self-reported functionally unstable ankle.

The purposes of this study were (1) to compare the single-leg balance ability and functional outcome scores of subjects with a self-reported functionally unstable ankle with those of nonimpaired subjects, and (2) to quantify in unstable ankles and nonimpaired ankles the effects of a 4-week balance training program on both balance control and perceived functional ability.

We hypothesized that (1) subjects with a self-reported functionally unstable ankle joint (experimental group) would demonstrate inferior single-leg balance ability of both the involved limb and the uninvolved limb when compared to the nonimpaired subjects, (2) the balance training program used in this study would improve single-leg balance ability to a greater extent in the experimental group than in the nonimpaired group, and (3) the posttraining balance indices of the functionally unstable group would be similar to those of the nonimpaired group.

METHODS

Subjects

Twenty-six active university students (11 women and 15 men) volunteered as subjects for this study (Table 1). Subjects were included in this study if they presented with an active range of ankle joint motion of at least 15° of dorsiflexion and 45° of plantar flexion and were also able to complete the test tasks. Subjects were excluded from this study if they presented with ankle joint pain, joint swelling, a history of insulin-dependent diabetes mellitus, any rheumatologic disorders, or any systemic disease that might interfere with sensory input. All subjects gave written consent to participate in the study, which was approved by the University of Pittsburgh Investigatory Review Board.

TABLE 1. Subject characteristics.*

	Age (y)	Height (cm)	Weight (kg)
Experimental group	21.9 ± 3.1	172.9 ± 10.4	72.2 ± 18.0
Nonimpaired group	21.2 ± 2.5	169.4 ± 11.3	73.2 ± 19.1
All subjects	21.5 ± 2.7	171.2 ± 10.8	72.7 ± 18.2

* All values listed as mean ± standard deviation. For experimental group, n = 13, 5 women and 8 men. For the nonimpaired group, n = 13, 6 women and 7 men. For all subjects, n = 26, 11 women and 15 men.

The experimental group consisted of 13 subjects who reported having sustained at least 2 unilateral inversion ankle sprains and who were currently experiencing a sense of unilateral ankle weakness or instability or both. Unilateral ankle instability was defined as repeated episodes of "ankle rolling" and/or ankle "giving way." Thirteen healthy, uninjured subjects served as the comparison group.

Balance Assessment

To determine the objective effects of the balance training program, all subjects completed a single-leg static balance assessment for both limbs on the Biodex Stability System (Biodex, Shirley, NY). The Biodex Stability System is a commercially available dynamic postural stability assessment and training system. This device is designed to stimulate joint mechanoreceptors and to promote reflex muscular activation necessary for joint stability.[2] The Biodex Stability System consists of a movable balance platform, which provides up to 20° of surface tilt in a 360° range and is interfaced with a microprocessor-based actuator. The actuator controls the manually preset degree of surface instability, which ranges from a completely firm surface, stability level 8, to a very unstable surface, stability level 2.[2] The stability level simply indicates the predetermined stability or stiffness of the balance platform. The degree to which the platform tilts during a balance assessment is dictated by the subject's balance ability.

The dependent measurement obtained from the Biodex Stability System, which was used to determine the objective effects of the balance training program, was the Stability Index (SI). The SI was calculated

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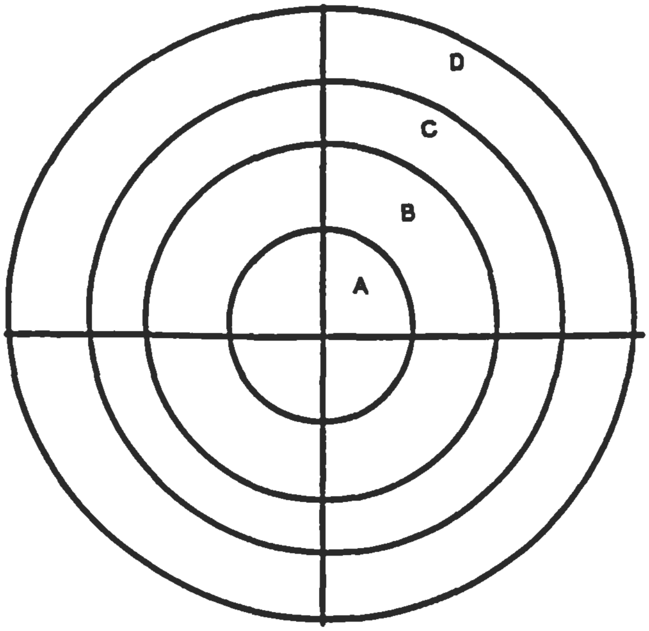
Anterior



Posterior

FIGURE 1. The bullseye of the Biodex Stability System's visual feedback screen.

online and quantified the subject's ability to control the platform's angle of tilt during a test. Therefore, the SI represented the variance of platform displacement in degrees from level in all motions during a test.[2] Specifically, the SI was calculated by summing the squares of all variations from the level position ($\Sigma\ (0 - X)^2 + (0 - Y)^2$) and dividing this value by the total number of samples.[2] A high SI (ie, 5.93) is indicative of a lot of movement during a test and therefore less stability. On the contrary, a lower SI (ie, 0.66) reflects less time spent away from the level position; a lower SI is therefore interpreted as a better balance score.

The reliability of the Biodex Stability System has been established with intraclass correlation coefficients (ICC) ranging from 0.6 to 0.95.[28] Specifically, the ICCs for a single-leg stance at stability level 8 (a stable platform) are 0.95 and 0.78 for the dominant and nondominant limbs, respectively.[28] In addition, the ICC for single-leg stance at stability level 2 is 0.60 for both the dominant and nondominant limbs.[28]

In a randomized order, subjects performed a single leg static balance test of both lower extremities at 2 stability levels: 6 (more stable) and 2 (less stable). The stability levels 6 and 2 were selected because they represent, respectively, a fairly stable platform surface and an unstable platform surface. For each test, trial subjects were asked to stand on a single leg on the platform with both arms across their chest and with the unsupported limb held in a comfortable position so as not to contact the test limb or the test platform. The subject's chosen test position was used for all practice and data collection trials. Instructions were given for the subjects to focus on a visual feedback screen directly in front of them and attempt to maintain the cursor, which represents the center of the platform, at the center of the bullseye on the screen (Figure 1). Keeping the cursor at the center of the bullseye on the screen equated to a level platform. For each test trial, subjects attempted to keep the platform level for 20 seconds. Two practice trials were completed before the first test condition, and 1 practice was allowed prior to all additional tests. A device-generated SI was recorded for each of the 3 trials under the 4 test conditions of (1) involved limb at level 6, (2) involved limb at level 2, (3) uninvolved limb at level 6, and (4) uninvolved limb at level 2. From the 3 trials a mean SI was calculated for each test condition.

Balance Training Program

Subjects in both groups participated in a 4-week, 3-days-per-week single-leg balance training program on the Biodex Stability System (Table 2). Subjects in the experimental group trained the involved limb, and the nonimpaired group members trained a randomly selected limb. The training program used in this study consisted of both static and dynamic balancing components. Moreover, the training program required the subjects to perform the training while standing in the same body position used during the testing.

The static balance component of the program required the subjects to balance on a single limb at a

TABLE 2. Balance training program.

Balancing component	Activity	Stability level	Number of sets	Duration (s)	Number of repetitions
Static	Single-leg stand	6	3	30	—
	Single-leg stand	2	3	30	—
Dynamic	A/P tilting	2	3	—	6
	M/L tilting	2	3	—	6
	CW circles	2	1	—	10
	CCW circles	2	1	—	10

A/P indicates anterior and posterior; M/L, medial and lateral; CW, clockwise direction; and CCW, counterclockwise direction.

high resistance to platform tilt (stability level 6) and a low resistance to platform tilt (stability level 2). Stability level 6, therefore, provides a more stable surface compared with stability level 2. Subjects were instructed to focus on the visual feedback screen directly in front of them and to attempt to maintain the cursor, which represents the platform, at the center of the bullseye on the screen (Figure 1). Essentially, the object of the static balancing component was to maintain the cursor for as long as possible at the center of the bullseye on the screen, which equated to sustaining a level platform. Subjects performed three 30-second repetitions of static balancing at both stability levels.

In contrast to the attempt to remain still in the static balance component of the balance training program, the objective of the dynamic balancing component was to actively move the platform within a specified range by relying on visual feedback from the balance device. The first component of the dynamic balance training program required each subject to actively tilt the platform in the single plane directions of (1) anterior and posterior tilt, and (2) medial and lateral tilt, while staying within the boundaries defined by the A-circle of the device's visual feedback screen (Figure 1). For both the anterior/posterior and medial/lateral tilting activities, subjects performed 3 sets of 6 repetitions. The second component of the dynamic balance training program required each subject to actively perform multiplane circles in both clockwise and counterclockwise directions. Subjects completed 1 set of 10 circle repetitions in both directions of movement. When moving the platform, the subjects attempted to trace the boundaries defined by the A-circle of the device's visual feedback screen (Figure 1). At the completion of the balance training program, all subjects performed a posttest that was identical in content and format to the pretest.

Ankle Joint Functional Assessment

The Ankle Joint Functional Assessment Tool (AJFAT) was composed of 12 questions rating the ankle's functional ability (Table 3). The 12 AJFAT questions were based on assessment tools previously used for evaluating the functional level of the knee joint.[25,26,29] It was necessary to design a functional assessment tool for this study because, in contrast to the diagnostic tools available for the knee joint, there does not appear to be a written assessment tool either for rating the ankle joint's performance during functional activities or for documenting subjective changes subsequent to intervention.

In completing the AJFAT, subjects were instructed to answer each question by checking the statement that at that time best described their involved or experimental ankle as compared with the contralateral ankle. Subjects were also instructed to check only 1 answer for each question, choosing the answer that best described their involved, experimental ankle. For each question, the 5 possible answers were assigned a point value, which ranged from 0 to 4 (Table 3). This value was unknown to the subjects. Answers representing a lower level of symptoms or a greater functional ability were assigned a greater value. Therefore, the maximal attainable score for each question was 4, and the minimal attainable value was 0.

To quantify the subjective effects of training, an overall AJFAT test score was obtained from the assessment tool. The overall test score was calculated by totaling the point values from the answers of the 12 questions (maximum value = 48). This value represented the subject's overall perceived level of function. A higher overall score represented a greater perceived functional ability of the involved ankle. This written assessment tool was completed by all subjects prior to and following the balance training program.

Data Analysis

Balance data The SIs obtained at stability level 2 were analyzed independently of those obtained during testing at stability level 6. Therefore, 2 separate 3-factor ANOVAs, with 2 levels for the first factor group (experimental and nonimpaired), 2 levels for the second factor test (pretest and posttest), and 2 levels for the third factor limb (trained and untrained), were employed. The fixed factors were group and test, and the random factor was limb. A nominal alpha of $P \leq .05$ was selected to determine statistical significance in this study. For significant interactions and main effects, the Tukey post hoc procedure was used to determine significant mean differences. All data were analyzed using SPSS for Windows 6.0 version software program (SPSS, Chicago, Ill).

Ankle functional assessment data A 2-factor ANOVA with 2 levels for the first factor group (experimental and nonimpaired) and 2 levels for the second factor test (pretest and posttest) was used to detect significant changes in overall AJFAT test scores as a result of the training program. As with the balance data, the Tukey post hoc procedure was used to determine significant mean differences when significant interactions and main effects existed. All data were analyzed using SPSS for Windows 6.0 version software program (SPSS).

RESULTS

Balance Data: Low Resistance to Platform Tilt (Stability Level 2)

Individual test means and standard deviations for the objective data from testing at stability level 2 (the

TABLE 3. Ankle Joint Functional Assessment Tool (AJFAT).

1. How would you describe the level of pain you experience in your ankle?
   - ____(4) Much less than the other ankle
   - ____(3) Slightly less than the other ankle
   - ____(2) Equal in amount to the other ankle
   - ____(1) Slightly more than the other ankle
   - ____(0) Much more than the other ankle
2. How would you describe any swelling of your ankle?
   - ____(4) Much less than the other ankle
   - ____(3) Slightly less than the other ankle
   - ____(2) Equal in amount to the other ankle
   - ____(1) Slightly more than the other ankle
   - ____(0) Much more than the other ankle
3. How would you describe the ability of your ankle when walking on uneven surfaces?
   - ____(0) Much less than the other ankle
   - ____(1) Slightly less than the other ankle
   - ____(2) Equal in ability to the other ankle
   - ____(3) Slightly more than the other ankle
   - ____(4) Much more than the other ankle
4. How would you describe the overall feeling of stability of your ankle?
   - ____(0) Much less stable than the other ankle
   - ____(1) Slightly less stable than the other ankle
   - ____(2) Equal in stability to the other ankle
   - ____(3) Slightly more stable than the other ankle
   - ____(4) Much more stable than the other ankle
5. How would you describe the overall feeling of strength of your ankle?
   - ____(0) Much less strong than the other ankle
   - ____(1) Slightly less strong than the other ankle
   - ____(2) Equal in strength to the other ankle
   - ____(3) Slightly stronger than the other ankle
   - ____(4) Much stronger than the other ankle
6. How would you describe your ankle's ability when you descend stairs?
   - ____(0) Much less than the other ankle
   - ____(1) Slightly less than the other ankle
   - ____(2) Equal in amount to the other ankle
   - ____(3) Slightly more than the other ankle
   - ____(4) Much more than the other ankle
7. How would you describe your ankle's ability when you jog?
   - ____(0) Much less than the other ankle
   - ____(1) Slightly less than the other ankle
   - ____(2) Equal in amount to the other ankle
   - ____(3) Slightly more than the other ankle
   - ____(4) Much more than the other ankle
8. How would you describe your ankle's ability to "cut," or change direction, when running?
   - ____(0) Much less than the other ankle
   - ____(1) Slightly less than the other ankle
   - ____(2) Equal in amount to the other ankle
   - ____(3) Slightly more than the other ankle
   - ____(4) Much more than the other ankle
9. How would you describe the overall activity level of your ankle?
   - ____(0) Much less than the other ankle
   - ____(1) Slightly less than the other ankle
   - ____(2) Equal in amount to the other ankle
   - ____(3) Slightly more than the other ankle
   - ____(4) Much more than the other ankle
10. Which statement best describes your ability to sense your ankle beginning to "roll over"?
    - ____(0) Much later than the other ankle
    - ____(1) Slightly later than the other ankle
    - ____(2) At the same time as the other ankle
    - ____(3) Slightly sooner than the other ankle
    - ____(4) Much sooner than the other ankle

TABLE 3. Continued.

11. Compared with the other ankle, which statement best describes your ability to respond to your ankle beginning to "roll over"?
    - ____(0) Much later than the other ankle
    - ____(1) Slightly later than the other ankle
    - ____(2) At the same time as the other ankle
    - ____(3) Slightly sooner than the other ankle
    - ____(4) Much sooner than the other ankle
12. Following a typical incident of your ankle "rolling," which statement best describes the time required to return to activity?
    - ____(0) More than 2 days
    - ____(1) 1 to 2 days
    - ____(2) More than 1 hour and less than 1 day
    - ____(3) 15 minutes to 1 hour
    - ____(4) Almost immediately

less stable platform) are presented in Table 4. Results of the ANOVA for data obtained during testing at stability level 2 revealed a significant 3-way interaction of group by test by limb ($F_{1,24}$ = 4.78, $P < .05$), a significant test by limb interaction ($F_{1,24}$ = 18.53, $P < .05$), and a significant main effect for the variable-labeled test ($F_{1,24}$ = 83.63, $P < .01$) (Figure 2).

Tukey post hoc analysis on the trained limb data determined the following: (1) the pretraining score of the experimental group (mean SI = 5.93 ± 3.65) was significantly higher than the nonimpaired group mean SI score (4.67 ± 3.43), indicating significantly poorer balance ability in the experimental group at the beginning of the study; (2) the mean posttraining SI scores of both the experimental group (2.63 ± 1.92) and the nonimpaired group (2.69 ± 2.32) were significantly lower than their respective pretraining scores, indicating a significant improvement in balance ability; and (3) there was no significant difference when comparing the posttraining scores of the 2 groups.

Tukey post hoc analysis on the untrained limb data revealed the following: (1) the mean pretraining SI score of the experimental group (4.53 ± 3.29) was not significantly higher than the mean pretraining SI score of the nonimpaired group (4.29 ± 2.99); (2) the mean posttraining SI score of the experimental group (3.81 ± 3.41) was not significantly lower than the mean pretraining SI score; (3) the

TABLE 4. Stability indices obtained at platform stability level 2.

	Pretraining	Posttraining
Experimental group		
Trained limb	5.93 ± 3.65*	2.63 ± 1.92†
Untrained limb	4.53 ± 3.29	3.81 ± 3.41
Nonimpaired group		
Trained limb	4.67 ± 3.43	2.69 ± 2.32†
Untrained limb	4.29 ± 2.99	3.12 ± 2.40†

* Indicates significant mean difference ($P \leq .05$) when compared with the same limb of the nonimpaired group.
† Indicates significant mean difference ($P \leq .05$) when compared with pretraining values of the same limb.

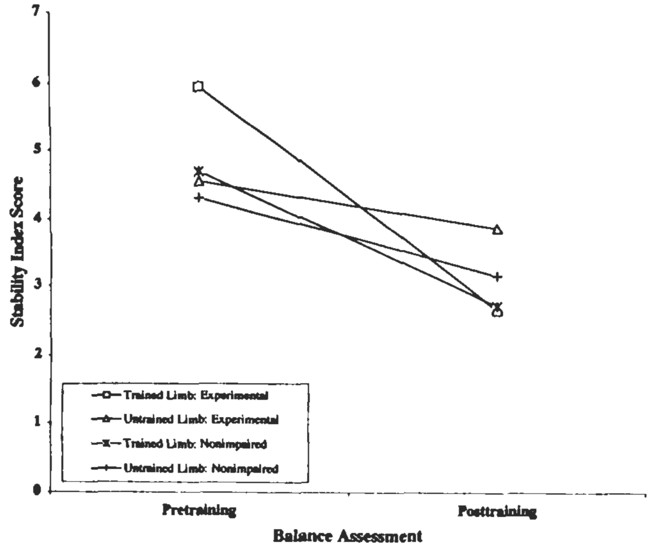


FIGURE 2. Mean Stability Indices from level 2 balance assessment: lower value represents greater stability. (Standard deviations listed in Table 4.)

mean posttraining SI score of the nonimpaired group was significantly lower than the pretraining score, indicating a significant improvement in balance ability; and (4) there was no significant difference when comparing the posttraining scores of the 2 groups.

Balance Data: High Resistance to Platform Tilt (Stability Level 6)

Individual test means and standard deviations for the objective data from testing at stability level 6 (more stable platform) are presented in Table 5. Results of the ANOVA for data obtained during testing at stability level 6 revealed a significant test by limb interaction ($F_{1,24} = 1.78$, $P < .05$) and a significant main effect for the variable-labeled test ($F_{1,24} = 8.87$, $P < .01$) (Figure 3).

Tukey post hoc analysis on the trained limb data determined the following: (1) there was no significant difference when comparing the pretraining scores of the 2 groups; (2) the mean posttraining SI scores of both the experimental group (1.27 ± 0.66) and the nonimpaired group (1.37 ± 0.66) were significantly lower than their pretraining scores (2.30 ± 1.88 and 2.04 ± 1.43, respectively), indicating a significant improvement in balance ability; and (3) there was no significant difference revealed when comparing the mean posttraining scores of the 2 groups.

Tukey post hoc analysis on the untrained limb determined the following: (1) there was no significant difference when comparing the pretraining scores of the 2 groups; (2) the mean posttraining score of the experimental group (1.56 ± 0.97) was significantly lower than its pretraining score (2.08 ± 1.41), indicating a significant improvement in balance ability; (3) the mean posttraining score of the nonimpaired group (1.69 ± 1.05) was not significantly lower than its pretraining score (1.82 ± 1.06); and (4) there was no significant difference revealed when comparing the posttraining scores of the 2 groups.

TABLE 5. Stability indices obtained at platform stability level 6.

	Pretraining	Posttraining
Experimental group		
Trained limb	2.30 ± 1.88	1.27 ± 0.66*
Untrained limb	2.08 ± 1.41	1.56 ± 0.97*
Nonimpaired group		
Trained limb	2.04 ± 1.43	1.37 ± 0.66*
Untrained limb	1.82 ± 1.06	1.69 ± 1.05

* Indicates significant mean difference ($P \leq .05$) when compared with pretraining values of the same limb

Ankle Joint Functional Assessment Data

The means and standard deviations for the subjective data (overall AJFAT test scores) are presented by group in Table 6. Results of the ANOVA revealed a significant difference between pretest and posttest total AJFAT scores ($F_{1,20} = 18.10$, $P < .01$). Tukey post hoc analyses determined the following: (1) the mean pretraining score of the experimental group (17.11 ± 3.44) was significantly lower than the pretraining score of the nonimpaired group (22.92 ± 5.22), indicating significantly less perceived ankle joint functional ability in the experimental group at the beginning of the study; (2) the mean posttraining scores of both the experimental group (25.78 ± 3.80) and the nonimpaired group (29.15 ± 5.27) were significantly higher than their respective pretraining scores, indicating an overall improvement in perceived ankle joint functional stability; and (3) there was no significant difference between the posttraining scores of the 2 groups (Figure 4).

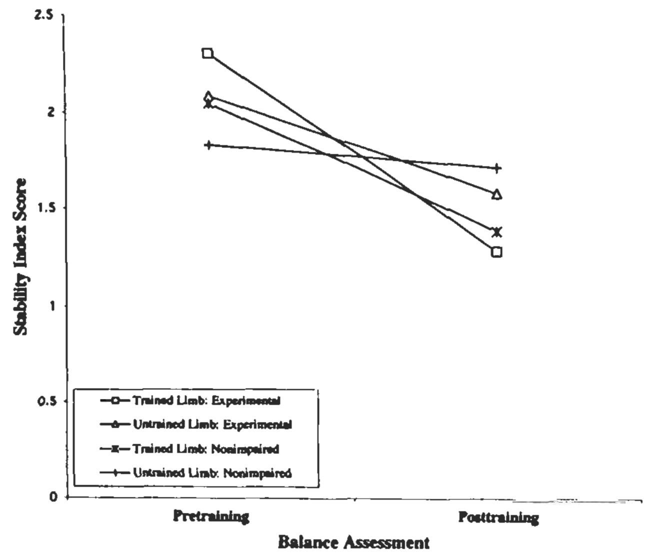


FIGURE 3. Mean Stability Indices from level 6 balance assessment: lower value represents greater stability. (Standard deviations listed in Table 5.)

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TABLE 6. Written Ankle Joint Functional Assessment Tool (AJFAT) total scores.

	Pretraining	Posttraining
Experimental group	17.11 ± 3.44*	25.78 ± 3.80†
Nonimpaired group	22.92 ± 5.22	29.15 ± 5.27†

* Indicates significant mean difference ($P \leq .05$) when compared with the pretraining score of the nonimpaired group.
† Indicates significant mean difference ($P \leq .05$) when compared with pretraining values of the same limb.

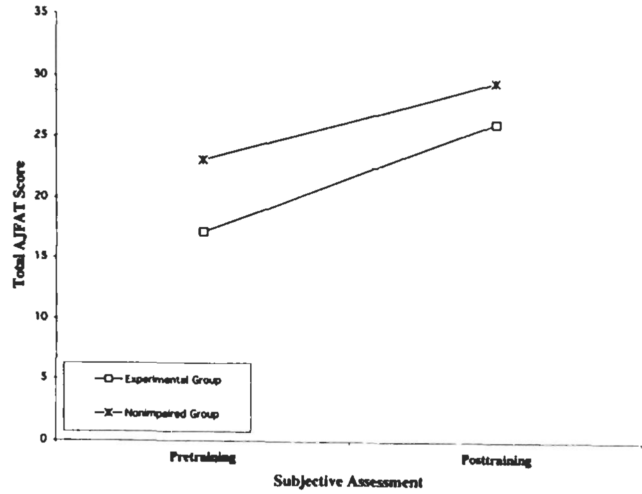

FIGURE 4. Ankle Joint Functional Assessment Tool (AJFAT) mean total score: greater value indicates a lower level of symptoms and a greater functional ability. (Standard deviations listed in Table 6.)

DISCUSSION

The primary goal of our investigation was to quantify, through the use of balance stabilometry, the effects of a 4-week single-leg balance training program on both the functionally unstable and the nonimpaired ankle joint. The assessment of balance ability is one method of determining the efferent, or the muscular response to afferent stimulation. Balance has been said to be mediated by the same peripheral afferent mechanism that mediates joint proprioception, but it may be more representative of lower extremity function when compared to assessments performed in a non–weight-bearing position.[15,23]

Assessed at stability level 2 prior to training, the balance ability of the trained limb of individuals with unstable ankles was significantly inferior (higher SI) compared to the trained limb of the nonimpaired individuals (Table 4). This significant difference represented a 27% deficit in the single-leg balance ability of the individuals with ankle instability. Less stability in single-limb standing suggests an altered proprioceptive response, which has been suggested to result in impaired or delayed lower extremity motor control.[7,8] Unable to effectively produce protective reactive muscular activation, such ankle joints may be at increased risk of repetitive ligamentous trauma.

Interestingly, the deficit in balance ability observed in the involved limb of the individuals with unstable ankles was also evident in their uninvolved limb. These pretraining bilateral balance deficits appear to indicate that individuals with a functionally unstable ankle joint may have a deficit in lower extremity postural reactions. Individuals with ankle instability may be at greater risk of ankle joint ligamentous injury to both lower extremities, as compared with nonimpaired persons, because they may be unable to effectively activate ankle muscles to protect the ankle joint from excessive joint motion. Therefore, rehabilitation programs prescribed to address existing proprioceptive deficits and to restore functional stability of patients with unstable ankles could have additional rehabilitative and preventative benefits when performed by both the involved and uninvolved ankle.

Although the individuals with a functionally unstable ankle began our study with poorer involved limb single-leg balance scores, their posttraining scores were almost identical to the posttraining scores of the healthy individuals. Rather than attaining the pretraining level of the nonimpaired individuals, which may be considered to be a normal level, they improved beyond this point to the posttraining level of the nonimpaired individuals. The similarity of posttraining scores among impaired and nonimpaired subjects indicates that the 4-week training program produced a greater treatment effect for the individuals with an unstable ankle than for the healthy individuals. The improvements in single-leg balance ability seen in the trained limb of our subjects following the completion of 4 weeks of balance training appear to be consistent with other studies involving balance training programs for individuals with a functionally unstable ankle[9] and healthy, uninjured individuals.[1,6,13] In a multicenter training study conducted by France et al[6] healthy individuals demonstrated improvements in single-leg balance ability following a balance training program, as compared with the untrained control group. Balogun et al[1] and Hoffman and Payne[13] also demonstrated that nonimpaired subjects made significant improvements in static balance ability after participating in a unilateral balance training program.

Our study showed a training effect on the untrained limb of the individuals with unstable ankles when balance was assessed at level 6; the study also showed a training effect on the untrained limb of the nonimpaired individuals when balance was assessed at stability level 2. The posttraining balance scores of the untrained limbs of both groups were better than (lower SI) all pretraining scores, regardless of limb or group. These findings are supported by Gauffin's[9] study of the effect of balance training for the unstable ankles of male soccer players. As a result of the training program, the soccer players recorded improved postural control when standing on the trained limb and when balancing on the contralateral untrained limb.[9] The balance score improvements in the contralateral, untrained limb of our subjects appear to suggest that our training program effectively stimulated centrally mediated neuromuscular control mechanisms responsible for the maintenance of balance and posture.

It is interesting to note that our study demonstrated improvements in balance ability after a training period of only 4 weeks. This training period, although shorter in duration than previously documented balance training programs,[1,6,13] produced improvements in the trained and contralateral untrained limbs of both the healthy participants and those with a functionally unstable ankle. These findings appear to indicate that 4 weeks is sufficient time to promote reflex muscular activation patterns necessary for the maintenance of posture and balance.

To objectively measure balance training effects, this study employed the Biodex Stability System (Biodex Inc, Shirley, NY), which is a commercially available dynamic postural stability assessment and training system. Even though the reliability of this device as an objective assessment of static balance ability has been investigated, the reported ICC values for single-leg stance at stability level 2 is only 0.60 for both the dominant and nondominant limbs.[28] In addition, the reliability of assessing balance with this device at stability level 6 has yet to be established.[28] Although this device appears to be an effective means of assessing and training lower extremity balance for the purpose of improving ankle joint functional stability, researchers and clinicians should consider the reported and yet unestablished reliability measurements of this device when weighing the findings of this investigation.

In addition to documenting the objective effects of a balance training program, this study aimed at quantifying the subjective effects of a unilateral balance training program on ankle stability. Our functional assessment tool has not yet been validated, and the results and conclusions drawn from this written questionnaire should be considered similar in nature to preliminary experimental observations. When considering the total functional assessment tool scores of both the unstable ankle individuals and the healthy individuals, the functional assessment questionnaire scores appear to mirror the findings from the balance assessment. Prior to training, the unstable ankle individuals demonstrated overall functional ability scores that were lower than those of the nonimpaired individuals, indicating a lower overall perceived functional ability of the ankle joint. As a result of participation in the single-leg balance training program, all subjects demonstrated an increase in the total functional assessment tool score, indicating an overall improvement in perceived ankle joint functional stability. The improvement in perceived functional ability occurred concurrently with improvements in the balance scores for both groups. Although the reliability and validity of the AJFAT has yet to be established, it appears to be an assessment tool that may aid researchers and clinicians in rating the functional ability of the ankle and in documenting subjective changes following intervention.

CONCLUSION

As a result of training, the balance ability of the trained limb in both the experimental group and nonimpaired group improved significantly to reach almost identical SIs. These improvements in balance ability appear to reflect improved neuromuscular ability along with enhanced functional joint stability, because the functional assessment questionnaire scores demonstrated the same treatment effects illustrated by the balance scores. The results of our study suggest that the balance training protocol used in this study is an effective means of improving both unstable and healthy ankle joint proprioception, as assessed through single-leg standing ability.

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