Journal of Athletic Training 2014;49(2):181–191
doi: 10.4085/1062-6050-49.2.06

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original research

Bilateral Improvements in Lower Extremity Function After Unilateral Balance Training in Individuals With Chronic Ankle Instability

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Context: Bilateral improvements in postural control have been reported among individuals with acute lateral ankle sprains and individuals with chronic ankle instability (CAI) when only the unstable ankle is rehabilitated. We do not know if training the stable ankle will improve function on the unstable side.

Objective: To explore the effects of a unilateral balance-training program on bilateral lower extremity balance and function in individuals with CAI when only the stable limb is trained.

Design: Cohort study.

Setting: University clinical research laboratory.

Patients or Other Participants: A total of 34 volunteers (8 men, 26 women; age = 24.32 ± 4.95 years, height = 167.01 ± 9.45 cm, mass = 77.54 ± 23.76 kg) with CAI were assigned to the rehabilitation (n = 17) or control (n = 17) group. Of those, 27 (13 rehabilitation group, 14 control group) completed the study.

Intervention(s): Balance training twice weekly for 4 weeks.

Main Outcome Measure(s): Foot and Ankle Disability Index (FADI), FADI Sport (FADI-S), Star Excursion Balance Test, and Balance Error Scoring System.

Results: The rehabilitation and control groups differed in changes in FADI-S and Star Excursion Balance Test scores over time. Only the rehabilitation group improved in the FADI-S and in the posteromedial and anterior reaches of the Star Excursion Balance Test. Both groups demonstrated improvements in posterolateral reach; however, the rehabilitation group demonstrated greater improvement than the control group. When the groups were combined, participants reported improvements in FADI and FADI-S scores for the unstable ankle but not the stable ankle.

Conclusions: Our data suggest training the stable ankle may result in improvements in balance and lower extremity function in the unstable ankle. This further supports the existence of a centrally mediated mechanism in the development of postural-control deficits after injury, as well as improved postural control after rehabilitation.

Key Words: overflow, crossover training, rehabilitation

Key Points

- The rehabilitation group performed better over time on the Foot and Ankle Disability Index Sport and the Star Excursion Balance Test (SEBT) in the anterior, posteromedial, and posterolateral directions, but this was not dependent on ankle.
- Training the stable ankle may provide therapeutic benefit to the unstable ankle.
- Performance on the Balance Error Scoring System did not reflect a therapeutic benefit of the neuromuscular-control training program, but the result should be interpreted with caution.
- Clinicians should consider incorporating rehabilitation of the stable ankle in the overall plan for patients who may not be ready to initiate aspects of rehabilitation on the unstable ankle.

Lateral ankle sprain (LAS) is one of the most common injuries that athletes and recreationally active individuals sustain. Researchers have estimated that approximately 23 000 ankle sprains occur each day in the United States, equating to 1 sprain per 10 000 people.[1] As many as 33% to 42% of these injuries result in chronic ankle instability (CAI).[2,3] In the literature, *CAI* has been defined as the tendency of the ankle to "give way" during normal activity and can occur in the absence of mechanical instability.[4–6] One explanation for this tendency is that damage to the peripheral mechanoreceptors that provide proprioceptive input results in altered efferent modulation. Together, the changes in afferent input and efferent output are recognized as altered neuromuscular control (NMC). When specifically considering the role of NMC in facilitating joint stability, *NMC* has been defined as "the unconscious activation of dynamic restraints occurring in preparation for and in response to joint motion and loading."[7] Ultimately, altered NMC is thought to result in functional ankle instability.[3,4,8] Even after the injury has healed, mechanoreceptors may not function properly, resulting in NMC deficits that can lead to CAI.[3,8]

In addition to damage at the level of the receptors, changes in central nervous system processing and integration also may contribute to CAI.[9,10] Evidence has suggested that when an injury occurs, this central mechanism for

NMC is disrupted.[9–12] Reports of bilateral postural-control deficits after acute LAS have provided further evidence that central pathways are affected by injury.[9,10,13] In addition, researchers[10,14–16] have found bilateral improvements in NMC and postural stability after rehabilitation of acute LAS and CAI. This suggests that NMC is not controlled solely by peripheral mechanoreceptors and that deficits after LAS may be partly due to adaptations in the central pathways. Whereas investigators[10,14–16] have shown a carryover effect after training the involved lower extremity, no one has examined whether training the stable ankle results in improvements to the unstable ankle.

Given these reports of bilateral deficits after unilateral injury and improvements in NMC and postural stability in the stable ankle after training only the unstable ankle, it is conceivable that training the stable ankle in individuals with CAI would result in improvements of the unstable ankle. This is meaningful because clinicians may be able to begin neuromuscular retraining earlier and the athlete may be able to return to sport participation better prepared without increasing the time missed. After an acute LAS, many athletes return to sport participation within 15 days[17] despite postural-control deficits being measured up to 21 days after injury[9] and many reporting pain and functional deficits 6 months later.[17] Researchers[18] also have recommended that NMC training should not begin immediately because of pain and weight-bearing restrictions. Therefore, the amount of time spent restoring NMC before return to sport participation is minimal, likely resulting in athletes returning with residual dysfunction and increased risk for reinjury. By beginning NMC retraining sooner, it is plausible that athletes may return to sport participation with less dysfunction and more prepared for the functional demands of sport. Therefore, the purpose of our study was to explore the effects of a 4-week, unilateral balance-training program on bilateral lower extremity balance and function in individuals with CAI. Our hypothesis was that bilateral improvements would occur after training of the stable ankle.

METHODS

Participants

Thirty-four people (8 men, 26 women; age = 24.32 ± 4.95 years, height = 167.01 ± 9.45 cm, mass = 77.54 ± 23.76 kg) with a history of CAI volunteered for this study by responding to a campus-wide e-mail invitation. The first 17 volunteers formed the rehabilitation group, and the second 17 composed the control group. Of the 34 volunteers for whom we collected data at baseline, 13 reported bilateral CAI. Seven volunteers (4 rehabilitation group, 3 control group) did not return for posttesting because of schedule conflicts. Of those 7 volunteers, 4 had bilateral CAI. No participant withdrew from the study because of adverse effects of the treatment program. Thus, complete data were available for 27 participants (13 rehabilitation group, 14 control group). All participants provided written informed consent, and the study was approved by the Institutional Review Board at Shenandoah University.

To establish eligibility for participation, we modified a questionnaire from Kaminski et al[19] and administered it to each volunteer to confirm the presence of CAI. Although psychometric data for this questionnaire have not been published, it has been used in several studies.[20–22] Currently, no diagnostic criteria for CAI are universally accepted and evidence based. We included volunteers if they reported a history of more than 1 ankle sprain, had not sustained an ankle sprain in the 6 months before the study, were between the ages of 13 and 35 years, reported a feeling of the ankle giving way, and attributed this instability to previous ankle sprains. We excluded volunteers if they reported a history of ankle fracture, anterior cruciate ligament injury, or balance or vestibular disorder or were undergoing any type of physical rehabilitation for the lower extremity at the time of the study.

Testing Procedures

At baseline testing, we administered the Foot and Ankle Disability Index (FADI), FADI Sport (FADI-S), Star Excursion Balance Test (SEBT), and Balance Error Scoring System (BESS) to the rehabilitation and control groups for both the unstable and stable ankles. We defined the *unstable ankle* as the ankle the participant reported as giving way and the *stable ankle* as the ankle the participant reported as more steady. If the participant had bilateral CAI, a stable ankle was assigned manually in a systematic random fashion. We counterbalanced the order of tests and test items (SEBT reach directions, BESS test conditions) to prevent order from affecting the data. Participants from both groups returned for follow-up testing, which was identical to the baseline testing, 4 weeks later.

The FADI and FADI-S. The FADI assesses activities of daily living related to ankle function, and the FADI-S evaluates sport-specific tasks**.** The items for both tests are scored on a Likert scale from 0 (*unable to do*) to 4 (*no difficulty at all*), and the total score for each test is converted into a percentage, with 100% indicating *no dysfunction*. The FADI consists of 26 items with a total possible score of 104 points, and the FADI-S consists of 8 items with a total possible score of 32 points. Both tests have moderate to good intersession reliability (intraclass correlation coefficient [ICC] = 0.84–0.93), are sensitive to differences between individuals with and without CAI, and are responsive to improvements after rehabilitation.[20]

The SEBT. The SEBT evaluates dynamic balance with a series of unilateral balance tests in which the participant is instructed to stand on 1 lower extremity while reaching a maximal distance with the other lower extremity.[23] This test originally was designed to assess reach in 8 directions. The SEBT has moderate to good intratester reliability (ICC = 0.78–0.96),[23] identifies reach deficits between ankles in individuals with CAI, identifies reach differences between individuals with and without CAI,[22,24] and responds to improvements after rehabilitation.[21]

Researchers[22] have shown redundancy in the 8 directions originally described in the SEBT. To avoid this redundancy, we used a modified version of the SEBT with only 3 directions (anterior, posterolateral [PL], and posteromedial [PM]). We chose the anterior direction for its simplicity in familiarizing the participants with the test. We selected the PL and PM directions because they have been shown to respond to improvements after rehabilitation.[21] The PM direction is also the most predictive of performance in all directions.[22] For the anterior reach, the participant started with the great toe of the stance foot positioned just behind a line demarcating the center of the grid. For the PM and PL directions, the heels were placed just in front of the line demarcating the center of the grid. We instructed the participants to place hands on hips for the duration of each trial. From the start position, he or she assumed single-limb stance and reached with the opposite leg as far as possible in each of the 3 directions. At the end of each reach, the participant tapped the great toe of the reaching limb to the tape and then immediately returned to the start position. To minimize a learning effect, 6 practice trials were afforded in each direction.[23] After the practice trials, the participant completed 3 measured trials. The mean of the 3 measured trials was normalized to the participant's height, as described by Gribble and Hertel,[25] and recorded for analysis.

The BESS. The BESS was designed to evaluate static balance by measuring the ability of the participant to maintain the test position for 20 seconds with the eyes closed under 6 conditions: bipedal stance, single-limb stance, and tandem stance performed on both firm and foam surfaces**.** The BESS has fair to good intratester reliability in healthy athletes (ICC = 0.87–0.98)[26,27] and has been reported to detect differences between individuals with and without CAI.[28]

The participants performed conditions requiring a firm surface on a tile floor and those conditions requiring a foam surface on a piece of 19.5-in (49.5-cm)-long × 16-in (40.6-cm)-wide × 2.5-in (6.4-cm)-high medium-density foam for double- and single-limb activities and on a 62-in (157.5-cm)-long × 8-in (20.3-cm)-wide × 2.5-in (6.4-cm)-high medium-density foam balance beam for tandem-stance activities. We instructed the participants to remain in the test position for 20 seconds with their hands on their iliac crests, heads up, and eyes closed. An error was recorded each time participants engaged in any of the following: (1) lifting hands off the iliac crests; (2) opening their eyes; (3) stepping, stumbling, or falling; (4) moving the hip more than 30° in any direction; (5) lifting any part of the heel; or (6) remaining out of the position for more than 5 seconds. If participants committed 2 errors simultaneously, only 1 error was recorded.

Training Protocol

The rehabilitation group participated in the training protocol twice per week for 4 weeks, and the control group was instructed to continue their normal activities. Each training session lasted about 30 minutes. The training protocol consisted of supervised exercise with a focus on restoring static and dynamic postural control (Figure 1). The exercises were selected to reflect common exercises used in clinical practice and exercises previously reported in similar intervention studies.[15,16,19,21,29–31] The exercise program of each participant was progressed based on his or her performance during the training sessions. To ensure consistency among participants, we developed specific criteria for progression (Figure 1). During the treatment session, participants performed the exercises with only the stable ankle.

Statistical Analysis

We used independent t tests to compare the rehabilitation and control groups at baseline on the BESS bipedal conditions. To compare the rehabilitation and control groups and the stable and unstable ankles at baseline on all other tests, we calculated separate 2 × 2 repeated-measures analyses of variance for each dependent variable. The between-subjects factor was group (rehabilitation, control), and the within-subject factor was ankle (stable, unstable). When examining side-to-side differences at baseline, we analyzed data only from participants with unilateral instability. To examine the effects of the training program, we calculated separate 2 × 2 × 2 repeated-measures analyses of variance for each dependent variable. The between-subjects factor was group (rehabilitation, control), and the within-subject factors were ankle (stable, unstable) and time (pretest, posttest). When we found an interaction, we performed post hoc testing using paired and independent t tests with Bonferroni correction to determine where the within-groups and between-groups differences, respectively, occurred. We also calculated effect sizes (ESs) as the difference between means divided by the SD for all findings that were different. The absolute values for all ESs are reported. The SD for the pretreatment mean was used when calculating the ES between sessions. The SD for the control group or control ankle was used when calculating the ES between groups or ankles, respectively. We used SPSS (version 15.0 for Windows; SPSS, Inc, Chicago, IL) to calculate descriptive and inferential statistics and set the α level for all analyses a priori at .05.

RESULTS

Between-Groups and Within-Groups Comparisons at Baseline

We found no differences between groups at baseline for any outcome measure. However, we did identify a main effect for side for the FADI ($F_{1,19} = 24.49$, $P < .001$, ES = 1.01), FADI-S ($F_{1,19} = 44.83$, $P < .001$, ES = 1.40), SEBT anterior ($F_{1,19} = 6.82$, $P = .02$, ES = 0.27), and SEBT PM ($F_{1,19} = 9.90$, $P = .005$, ES = 0.36) at baseline (Table). When we combined the groups, participants performed better on the stable ankle than on the unstable ankle for each of these measures. We found no other differences between the stable and unstable ankles. No participant in either the rehabilitation or control group had any errors for the bipedal firm-surface condition on the BESS; therefore, we did not perform any analyses using these data.

Between-Groups and Within-Groups Comparisons Across Time

The FADI and FADI-S. We identified a time-by-group interaction ($F_{1,24} = 6.377$, $P = .02$) for FADI-S scores. When we combined data for both ankles, participants in the rehabilitation group reported an improvement in function at posttest ($t_{25} = 4.33$, $P < .001$, ES = 0.72, 95% confidence interval [CI] of difference = 6.32, 17.16), and participants in the control group reported no change in function ($t_{26} = 1.59$, $P = .12$, ES = 0.17, 95% CI of difference = –5.68, 7.20; Figure 2A).

Analysis of the FADI and FADI-S scores also revealed a side-by-time interaction for FADI ($F_{1,25} = 11.611$, $P = .002$) and FADI-S ($F_{1,24} = 18.666$, $P < .001$). Participants reported no changes in the stable ankle for either the FADI

Exercise	Description	Progression	Image
Single-legged stance	Performed up to 60 s per repetition for up to 3 repetitions. Performed with eyes opened and eyes closed.	Progressed when participants could complete a 60-s trial without a loss of balance. Increased no. of repetitions by 1. Changed surface from floor to using the DynaDisc.[a]	
Wobble board	Slowly moved the board in the plantar-flexion/dorsiflexion and inversion/eversion directions without letting the board contact the floor. Performed up to 10 repetitions in each direction.	Progressed when participant could complete the task without upper extremity support. Added rotational directions.	
Steamboats	Tied a 48-in Theraband[b] around the unstable ankle. Positioned stance foot 27 in from where Theraband[b] was tied. Performed up to 3 sets of 15 repetitions in each direction (hip flexion, extension, abduction, adduction).	Progressed when participants could complete the repetitions without a loss of balance or fatigue. Increased no. of repetitions from 10 to 15. Progressed to next level of resistance with the Theraband.[b]	
Single-legged hop	Hopped as far as comfortable in the anterior direction. Performed up to 15 repetitions.	Progressed when participants could perform the tasks with minimal ankle and hip motion and no loss of balance on landing. Increased no. of repetitions from 5 to 10 to 15. Encouraged increased distance to participants' tolerance. Progressed to medial, lateral, and posterior directions.	
Quadrant hop	Hopped in numbered squares clockwise and counterclockwise while maintaining single-legged stance.	Progressed when participants completed 2 sets of 5 hops without a loss of balance or fatigue. Made unanticipated directional changes where investigator randomly called out numbers.	

Figure 1. Training protocol. [a] Exertools, Petaluma, CA. [b] The Hygenic Corporation, Akron, OH.

(t_{26} = 1.20, P = .24, ES = 0.16, 95% CI of difference = –2.11, 0.55) or the FADI-S (t_{25} = 1.723, P = .10, ES = 0.24, 95% CI of difference = –6.42, 0.57), whereas they did report improvements for the unstable ankle on the FADI (t_{26} = 3.278, P = .003, ES = 0.52, 95% CI of difference = 1.58, 6.87) and the FADI-S (t_{26} = 4.163, P < .001, ES = 0.81, 95% CI of difference = 5.70, 16.82) when we combined groups (Figure 2B and C).

The SEBT. We identified a time-by-group interaction for the SEBT reach in all 3 directions: anterior ($F_{1,25}$ = 12.430, P = .002), PM ($F_{1,25}$ = 4.461, P = .045), and PL ($F_{1,25}$ = 6.840, P = .02). The rehabilitation group reached farther over time in the anterior (t_{25} = 4.72, P < .001, ES = 0.98, 95% CI of difference = 1.62, 4.12) and PM (t_{25} = 3.92, P = .001, ES = 0.67, 95% CI of difference = 2.10, 6.73) directions, whereas the control group demonstrated no change over time in the anterior (t_{27} = 1.99, P = .057, ES = 0.21, 95% CI of difference = –0.04, 2.37) or PM (t_{27} = 1.30, P = .21, ES = 0.19, 95% CI of difference = –2.38, 0.54) directions when we combined the data for both ankles.

Single-legged ball catch	Performed up to 3 sets of 20 tosses.	Progressed when participants could perform 20 tosses without a loss of balance. Tossed ball outside participants' base of support. Performed during stance on a DynaDisc.[a]	
Toe touchdowns	Maintained single-legged stance on a step while lowering the unstable ankle in the anterior, posterior, medial, and lateral directions until the foot contacted floor. Performed up to 3 sets of 10 repetitions.	Progressed when participants could complete all trials without a loss of balance and with good lower extremity alignment (no valgus collapse). Increased no. of repetitions from 5 to 10. Increased height of step from 4 in to 12 in in 2-in increments.	
Hop ups and downs	Hopped off step and landed in single-legged stance on floor. Performed up to 3 sets of 10 repetitions.	Progressed when participants could complete all hops without a loss of balance or fatigue. Increased no. of repetitions from 5 to 10. Increased height of step from 4 in to 12 in in 2-in increments. Changed direction of hop. Hopped up onto step.	

Figure 1. Continued from previous page.

When reaching in the PL direction, both the rehabilitation ($t_{25} = 4.67$, $P < .001$, ES = 1.24, 95% CI of difference = 3.28, 8.43) and control ($t_{27} = 3.84$, $P = .001$, ES = 0.38, 95% CI of difference = –2.91, –0.89) groups reached farther over time when we combined the data for both ankles, but the rehabilitation group demonstrated greater improvements than the control group (Figure 3A through C).

For reach distance in the PM direction, we noted a main effect for side. When we combined data for both groups at both times, participants reached farther in the PM direction when standing on the stable ankle than on the unstable ankle ($F_{1,25} = 5.081$, $P = .03$, ES = 0.19).

The BESS. For the BESS tandem-stance foam condition, we discovered a side-by-group interaction ($F_{1,25} = 4.363$, $P = .047$). When we combined data for both testing sessions, the control group committed more errors with the unstable ankle in front than did the rehabilitation group ($t_{59} = 2.73$, $P = .008$, ES = 0.77, 95% CI of difference = –3.09, –0.47), whereas we found no difference between groups when the stable ankle was in front ($t_{59} = 0.67$, $P = .51$, ES = 0.15, 95% CI of difference = –1.66, 0.83; Figure 4). We also noted a main effect for time for performance under the tandem-stance foam-surface condition. Participants performed better at posttest when we combined data for both groups and both ankles ($F_{1,25} = 9.272$, $P = .005$, ES = 0.50). For the single-limb–stance foam-surface condition, we identified a main effect for side ($F_{1,25} = 6.310$, $P = .02$, ES = 0.33). Participants committed a greater number of errors on their unstable ankles than on their stable ankles when we combined data for both groups at both times.

DISCUSSION

We examined the efficacy of a 4-week, unilateral balance-training program on bilateral lower extremity balance and function in individuals with CAI. Overall, the data supported our hypothesis. For the FADI-S and SEBT anterior, PM, and PL, participants in the rehabilitation group performed better over time, and this was not dependent on ankle. Participants in the control group did not show any change over time for the FADI-S or SEBT anterior or PM. For the SEBT PL, participants in the control group improved, but the improvement was greater among the participants in the rehabilitation group. These findings suggest that the unstable ankle improved even though participants performed rehabilitation on the stable ankle only.

Although randomization of our groups would strengthen these findings, the lack of between-groups differences at baseline provides some support for the validity of our findings. Scores for the FADI, FADI-S, and SEBT anterior and PM for all participants with unilateral CAI were greater for the stable ankle, indicating better postural stability and function and suggesting these measures are sensitive to deficits related to CAI. When we applied these baseline analyses to the results of the pretest-posttest analysis, we included only participants with unilateral instability in the

Table. Between-Groups and Within-Groups Comparisons at Baseline

Measure	Ankle	Chronic Ankle Instability Group, Mean ± SD		
		Rehabilitation (n = 12)	Control (n = 9)	Total (n = 21)
Foot and Ankle Disability Index	Unstable	87.92 ± 10.49	88.67 ± 8.79	88.24 ± 9.57
	Stable	96.67 ± 4.29	99.56 ± 1.33	97.90 ± 3.60[a]
Foot and Ankle Disability Index Sport	Unstable	71.00 ± 20.64	69.56 ± 12.61	70.38 ± 17.27
	Stable	92.42 ± 9.80	97.56 ± 5.46	94.62 ± 8.46[a]
Star Excursion Balance Test[b]				
Anterior reach	Unstable	36.17 ± 2.24	38.41 ± 6.53	37.13 ± 4.60
	Stable	37.37 ± 3.18	39.75 ± 6.38	38.39 ± 4.82[a]
Posteromedial reach	Unstable	41.50 ± 3.94	42.79 ± 5.09	42.05 ± 4.40
	Stable	42.45 ± 5.72	45.21 ± 4.07	43.63 ± 5.15[a]
Posterolateral reach	Unstable	36.65 ± 4.66	41.33 ± 5.05	38.66 ± 5.27
	Stable	38.33 ± 4.53	41.30 ± 3.98	39.60 ± 4.46
Balance Error Scoring System				
Bipedal stance, firm surface	Bipedal	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Single-limb stance, firm surface	Unstable	4.08 ± 3.06	3.78 ± 2.82	3.95 ± 2.89
	Stable	2.83 ± 2.08	2.44 ± 2.40	2.67 ± 2.18
Tandem stance, firm surface	Unstable	0.83 ± 1.11	1.78 ± 2.54	1.24 ± 1.87
	Stable	2.17 ± 4.51	0.78 ± 0.97	1.57 ± 3.47
Bipedal stance, foam surface	Bipedal	0.17 ± 0.58	0.33 ± 0.71	0.15 ± 0.50
Single-limb stance, foam surface	Unstable	8.67 ± 4.23	8.44 ± 3.28	8.57 ± 3.76
	Stable	8.08 ± 3.34	7.33 ± 3.64	7.76 ± 3.40
Tandem, foam surface	Unstable	3.42 ± 3.20	6.44 ± 1.94	4.71 ± 3.08
	Stable	3.67 ± 2.10	4.11 ± 3.33	3.86 ± 2.63

[a] Indicates difference compared with the unstable ankle when all participants with unilateral chronic ankle instability were pooled together ($P < .05$).
[b] Reported as a percentage of height.

baseline analysis. Thus, it is possible that the subset was slightly different from that analyzed at posttest. In addition, approximately 20% of our participants did not complete the study. Whereas this threatens the validity of our findings, the withdrawal rate between groups was similar, and none of the participants withdrew because of adverse effects of the study. This helps support the validity of our findings.

Several possible explanations exist for the bilateral improvements measured in our study. Changes in the central pathways of the central nervous system likely underlie the bilateral improvements observed. Researchers[9,10] have suggested that alterations may occur at the spinal or supraspinal level after injury. These centrally mediated changes, in turn, may result in bilateral postural-control deficits as reported after acute ankle sprain.[9] With proper rehabilitation, neuromuscular reeducation possibly can alter and enhance the central processing of afferent somatosensory information and the efferent response to the input. Several authors[14–16] have reported bilateral improvements in NMC and function in individuals with CAI after unilateral training. It is unlikely that the improvements measured in our study are due to participants training the unstable ankle independently, as they denied performing training outside of the supervised sessions. Given that the control group demonstrated few improvements and our outcome measures have been reported to be stable across time in individuals with CAI,[20,23,25] neither natural healing nor a learning effect explains the improvements we measured.

Although researchers[14–16] have reported bilateral improvements after unilateral training, we are the first to demonstrate that training the stable ankle may result in improvements to the unstable ankle. Before this study, researchers had reported improvements to only the stable ankle. Given the likely disruption of local mechanoreceptors, ligamentous structures, and possibly dynamic stabilizers in the affected ankle, it was not clear if the unstable ankle would demonstrate the same improvement that has been reported in the stable ankle. One also may have expected the patients' levels of confidence and anxiety to limit performance on the unstable lower extremity if they trained only the stable leg. We are the first to provide preliminary evidence that training the stable ankle may provide therapeutic benefit to the unstable ankle. In addition, our findings support those of Rozzi et al[16] that changes in the central mechanism of NMC may be achieved after only 4 weeks of rehabilitation.

Unexpectedly, scores on the FADI and FADI-S for the unstable ankle improved across time, and this was not dependent on whether the participant trained. We hypothesize that the rehabilitation group had such a large improvement in FADI and FADI-S scores for the unstable ankle compared with the control group that even when scores for both groups were combined, an improvement in the unstable ankle still was observed. We do not expect, however, that the improvements reported by the control group would be clinically important, as they reflect only a 1.8-point change (1.33%) on the FADI and a 6.5-point change (5.87%) on the FADI-S. In contrast, the rehabilitation group improved by 6.7 points on the FADI and 17.6 points on the FADI-S. Unfortunately, the minimal clinically important differences (MCIDs) for the FADI and FADI-S have not been established. However, the Foot and Ankle Ability Measure, which has the same sport subscale as the FADI and a very similar activities-of-daily-living subscale, is reported to have an MCID of 8 points for the activities-of-daily-living subscale and an MCID of 9 points for the sport subscale when used among those with musculoskeletal conditions of the leg, ankle, or foot.[32] The MCIDs for the FADI and FADI-S likely would be similar to those for

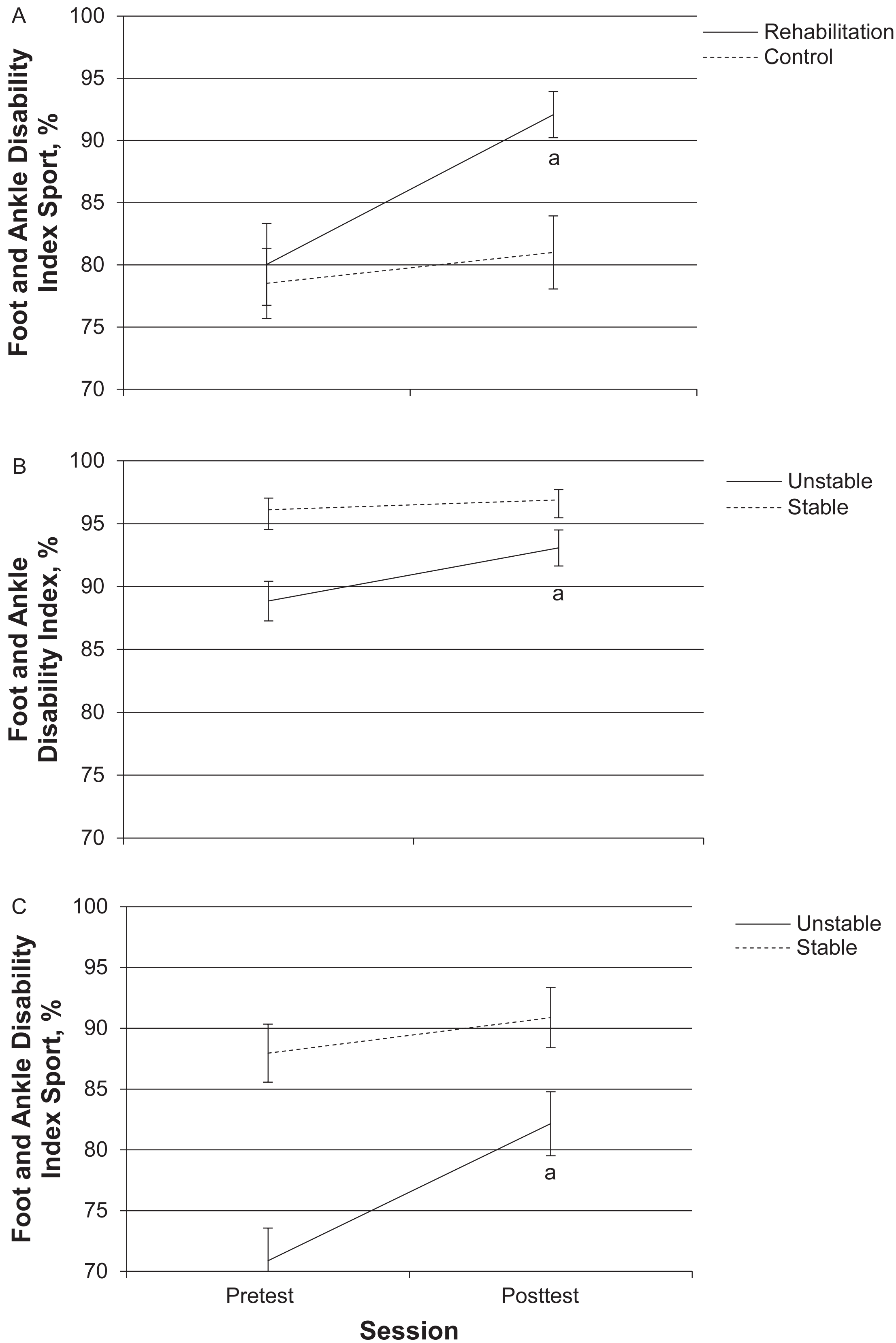

Figure 2. A, Interactive effect between time and group on Foot and Ankle Disability Index Sport scores (mean ± SE). [a] Indicates the Foot and Ankle Disability Index Sport scores differed between pretest and posttest ($P < .05$). B, Interactive effect between side and time on Foot and Ankle Disability Index scores (mean ± SE). [a] Indicates the Foot and Ankle Disability Index scores differed between pretest and posttest ($P < .05$). C, Interactive effect between side and time on Foot and Ankle Disability Index Sport scores (mean ± SE). [a] Indicates the Foot and Ankle Disability Index Sport scores differed between pretest and posttest ($P < .05$).

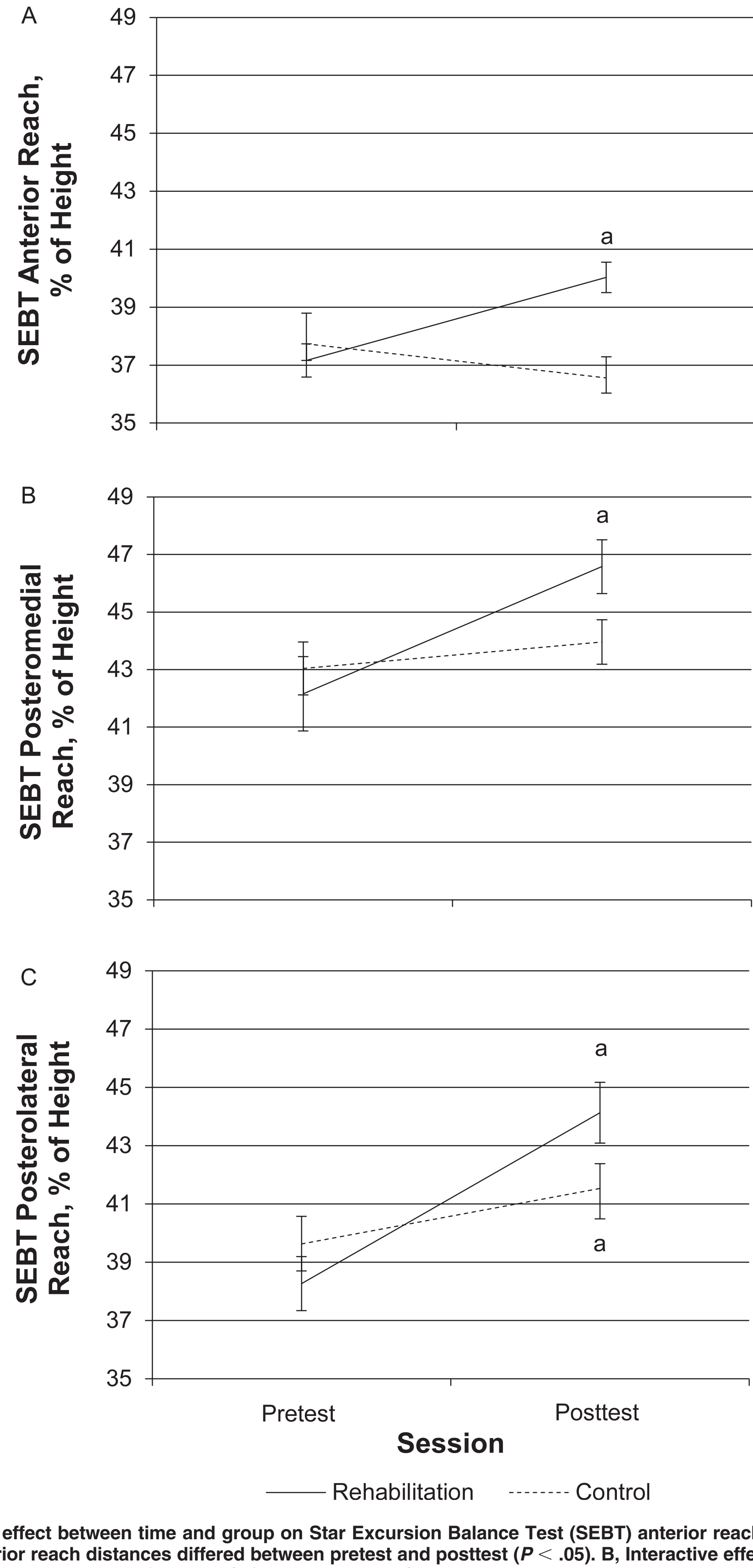

Figure 3. A, Interactive effect between time and group on Star Excursion Balance Test (SEBT) anterior reach distances (mean ± SE). [a] Indicates the SEBT anterior reach distances differed between pretest and posttest ($P < .05$). B, Interactive effect between time and group on SEBT posteromedial reach distances (mean ± SE). [a] Indicates the SEBT posteromedial reach distances differed between pretest and posttest ($P < .05$). C, Interactive effect between time and group on SEBT posterolateral reach distances (mean ± SE). [a] Indicates the SEBT posterolateral reach distances differed between pretest and posttest ($P < .05$).

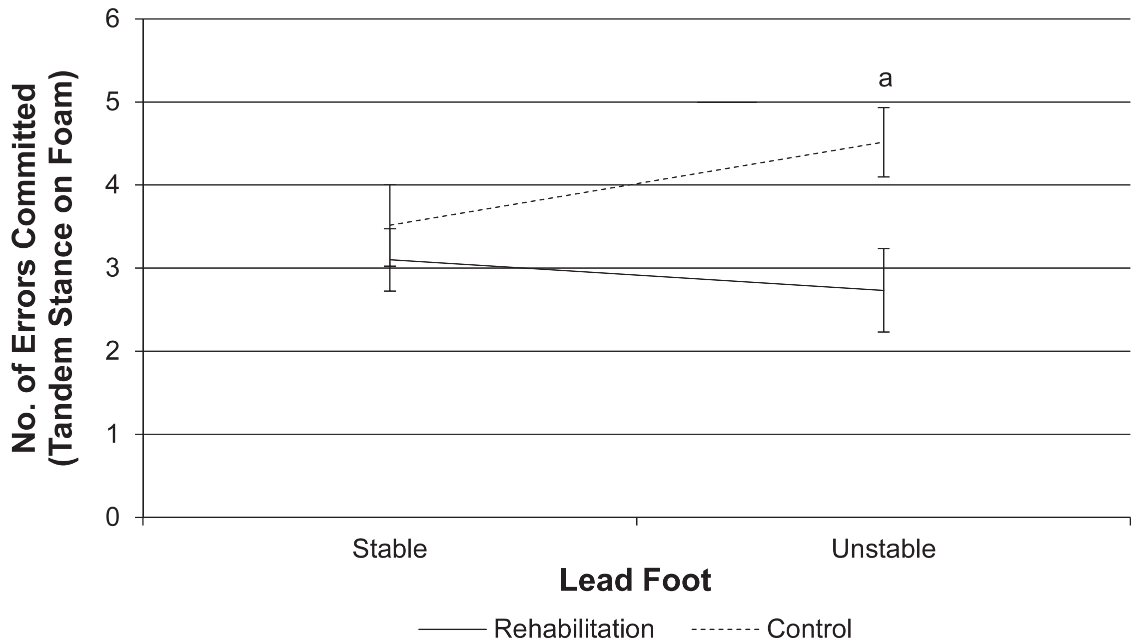

Figure 4. Interactive effect between side and group on Balance Error Scoring System scores (mean ± SE). [a] Indicates the Balance Error Scoring System scores differed between groups ($P < .05$).

the Foot and Ankle Ability Measure. Whereas the reported improvement over time possibly was due to a natural course of healing, this is unlikely based on a study[20] in which the authors reported the FADI and FADI-S were reliable over 4 weeks in participants with CAI.

Overall, the performance of our participants on the BESS did not reflect a therapeutic benefit of the NMC training program. We identified improvements in performance only when data from the tandem stance on a foam surface for both groups and both ankles were combined. Use of the BESS as a measurement tool in our study had several limitations. Although Docherty et al[28] found the BESS was sensitive in detecting differences between the stable and unstable ankles in individuals with CAI, this tool was not effective in detecting differences between ankles at baseline in our study. Given that individuals with CAI typically report the ankle giving way during functional tasks, measures of dynamic balance may be more appropriate. The reliability of the BESS when used among those with CAI also must be considered. It has been shown to be fair to good in individuals without CAI[26,27] but has not been established in participants with CAI. Finally, the responsiveness of the BESS has not been investigated in this population. Our results involving this tool, therefore, should be interpreted with caution.

Whereas our data suggested the presence of a carryover effect to the unstable ankle after training the stable ankle, additional research is needed. Investigators need to identify the optimal treatment guidelines to accelerate return to play, maximize function, and reduce the risk for reinjury. Examining the literature to identify the ideal treatment guidelines is difficult because great variability exists in the methods used. Our results and the work of others[21,33–35] suggest that improvements in balance do occur after only 4 weeks of training. When we compared our results with those of investigators using the same outcome measures in individuals who have completed a 6-week intervention program, it is unclear if a longer intervention period will have superior results. In a case report, O'Driscoll et al[36] reported larger ESs for SEBT reaches after training than we measured in our study. However, our ESs were similar to those reported by Sefton et al.[37] Yet given other variations in the methods and results of these studies, it is difficult to make a direct comparison. An ideal number of treatment sessions is also difficult to identify because of variations in other treatment guidelines and outcome measures and inconsistent evidence of a dose response. McKeon et al[35] performed a study similar to ours in which they examined the effects of balance training on the FADI and SEBT scores. Their participants completed 12 sessions over 4 weeks, whereas our participants completed only 8 sessions. The ESs for the FADI and FADI-S were greater in their study[35] than in our study. However, ESs for the SEBT were greater in our study than in their study.[35] These comparisons make it difficult to identify the most appropriate number of treatment sessions.

Future research involving a more diverse patient population also will help to validate and generalize our findings. Specifically, investigators need to study individuals with acute LAS; with and without mechanical instability, because we did not assess mechanical instability in our patient population; with unilateral and bilateral instability; in younger and older age groups; and with different baseline activity levels. In keeping with the recommendations of Hiller et al,[38] studying these populations separately in a series of studies may be best to maintain homogeneous groups and allow for clearer interpretation of the results. This will help clinicians to identify which subgroups likely will respond to various treatment approaches and to best apply the evidence to their clinical practices.

Despite the potential limitations we described, our data suggested the presence of a carryover effect to the unstable ankle after training the stable ankle. We did not see this in all dependent measures, which may be explained by the limitations outlined. This effect may have important clinical implications for the management of CAI, acute LAS, and other lower extremity injuries. By training the stable or uninvolved ankle, clinicians can begin NMC retraining before permitting individuals to bear weight on the involved or unstable ankle, before individuals complete the acute stage of healing, or despite other precautions or contraindications to exercise due to their injuries. Athletes with more chronic injuries may be able to perform NMC and functional retraining at higher levels than otherwise would be possible by initiating these protocols on the stable ankle. It is plausible that initiating these activities on the stable ankle will result in earlier improvements in postural control and function in the unstable ankle. Ultimately, the results may be shorter rehabilitation times, earlier return to sport participation or work, and decreased health care costs. This practice also may provide psychosocial benefits by enabling patients to participate in functional retraining earlier, thus promoting a continued connection with activities that motivate the patient.

In conclusion, we recommend that clinicians incorporate rehabilitation of the stable ankle as a part of the overall rehabilitation plan in patients with CAI. Our data provided preliminary evidence to suggest that this may result in carryover of gains in postural control and function to the unstable ankle.

ACKNOWLEDGMENTS

We thank Drs Trent Stone, Laura Kovnesky, Becky Caulwell, Karen Kupelian, and Elizabeth Gannon for their support during data collection. We also thank Dr Todd Telemeco for his assistance in the development of our figures and Dr Lisa McVey for her review of the manuscript. We recognize Dr Tamara Helton for her continual contributions throughout our research process.

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