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original research

Strength-Training Protocols to Improve Deficits in Participants With Chronic Ankle Instability: A Randomized Controlled Trial

Emily A. Hall, MS, LAT, ATC*; Carrie L. Docherty, PhD, ATC, FNATA*; Janet Simon, PhD, ATC†; Jackie J. Kingma, DPT, ATC, PA-C*; Joanne C. Klossner, PhD, LAT, ATC*

*School of Public Health, Indiana University, Bloomington; †College of Health Sciences, University of Toledo, OH

Context: Although lateral ankle sprains are common in athletes and can lead to chronic ankle instability (CAI), strength-training rehabilitation protocols may improve the deficits often associated with CAI.

Objective: To determine whether strength-training protocols affect strength, dynamic balance, functional performance, and perceived instability in individuals with CAI.

Design: Randomized controlled trial.

Setting: Athletic training research laboratory.

Patients or Other Participants: A total of 39 individuals with CAI (17 men [44%], 22 women [56%]) participated in this study. Chronic ankle instability was determined by the Identification of Functional Ankle Instability Questionnaire, and participants were randomly assigned to a resistance-band–protocol group (n = 13 [33%] age = 19.7 ± 2.2 years, height = 172.9 ± 12.8 cm, weight = 69.1 ± 13.5 kg), a proprioceptive neuromuscular facilitation strength-protocol group (n = 13 [33%], age = 18.9 ± 1.3 years, height = 172.5 ± 5.9 cm, weight = 72.7 ± 14.6 kg), or a control group (n = 13 [33%], age = 20.5 ± 2.1 years, height = 175.2 ± 8.1 cm, weight = 70.2 ± 11.1 kg).

Intervention(s): Both rehabilitation groups completed their protocols 3 times/wk for 6 weeks. The control group did not attend rehabilitation sessions.

Main Outcome Measure(s): Before the interventions, participants were pretested by completing the figure-8 hop test for time, the triple-crossover hop test for distance, isometric strength tests (dorsiflexion, plantar flexion, inversion, and eversion), the Y-Balance test, and the visual analog scale for perceived ankle instability. Participants were again tested 6 weeks later. We conducted 2 separate, multivariate, repeated-measures analyses of variance, followed by univariate analyses on any significant findings.

Results: The resistance-band protocol group improved in strength (dorsiflexion, inversion, and eversion) and on the visual analog scale ($P < .05$); the proprioceptive neuromuscular facilitation group improved in strength (inversion and eversion) and on the visual analog scale ($P < .05$) as well. No improvements were seen in the triple-crossover hop or the Y-Balance tests for either intervention group or in the control group for any dependent variable ($P > .05$).

Conclusions: Although the resistance-band protocol is common in rehabilitation, the proprioceptive neuromuscular facilitation strength protocol is also an effective treatment to improve strength in individuals with CAI. Both protocols showed clinical benefits in strength and perceived instability. To improve functional outcomes, clinicians should consider using additional multiplanar and multijoint exercises.

Key Words: functional ankle instability, functional performance, rehabilitation, Star Excursion Balance Test

Key Points

- Proprioceptive neuromuscular facilitation is an alternate strength-training protocol that was effective in enhancing ankle strength in those with chronic ankle instability.
- Neither the resistance-band protocol nor the proprioceptive neuromuscular facilitation protocol improved dynamic balance or functional performance in individuals with chronic ankle instability.

Lateral ankle sprains are very common in athletes[1] and account for 80% of injuries to the ankle.[2] These injuries can cause damage to the ligaments, muscles, nerves, and mechanoreceptors that cross the lateral ankle.[3] Repetitive occurrences of lateral ankle sprains can lead to chronic ankle instability (CAI),[4–6] which is characterized by a subjective feeling of recurrent instability, repeated episodes of giving way, weakness during physical activity, and self-reported disability.[5,7,8] Patients with CAI often exhibit deficits in functional performance,[9–13] proprioception,[5,14–16] and strength.[4,5,16,17]

Because muscle weakness is associated with CAI, strength training is an essential part of the rehabilitation protocol[17] to reduce the residual symptoms and, we hope, to prevent further episodes of instability from occurring. Strength training improves the physical conditioning of participants with ankle instability.[16,18–25] Strength training is thought to promote muscular gains during the first 3 to 5 weeks because it enhances neural factors.[26] Therefore, strength training may improve proprioception and balance deficits.[18,24,25] Conflicting findings exist in the current literature[14,23]; thus, the relationship between strength training and other factors, such as balance, proprioception, or functional performance, requires further investigation.

Most authors[18,20,21,23,25] who have investigated the effect of strength training in people with CAI have used resistive-tubing exercises 3 times/wk for 4 weeks[20] to 6 weeks.[18,21,23,25] Other rehabilitation protocols have involved manual resistance at the ankle[22] and isokinetic strength training.[24] Some researchers[18,21,23–25] focused on strength-training protocols alone, whereas others[19,20,22,27,28] have used multicomponent protocols that included balance exercises. Improvements in strength,[18,24,25] static balance,[24] joint position sense,[18] and functional performance tests[24] were reported.

Proprioceptive neuromuscular facilitation (PNF) is another form of progressive strength training that emphasizes multiplanar motion.[29] The goal of PNF techniques is to promote functional movement through facilitation (strengthening) and inhibition (relaxation) of muscle groups.[30] Although it is used more often at the shoulder, hip, and knee joints, PNF can also be used at the ankle.[31] Two studies[32,33] compared the differences between common lower extremity strength-training programs and PNF strength-training patterns. The PNF pattern for both studies used the sequential movements of toe flexion, ankle plantar flexion and eversion, knee and hip extension, abduction, and internal rotation in the lower extremity. The PNF strength patterns were as effective as isokinetic training[32] and weight training[33] in improving knee strength and functional performance. Based on the deficits seen in patients with CAI, PNF may be a beneficial treatment approach. Because PNF patterns are similar to functional movement patterns,[29] PNF strength techniques may also improve dynamic balance and functional performance.

Although a multicomponent rehabilitation protocol is often used after an injury, examining 1 component, such as strength, in a controlled research setting will allow us to determine the effectiveness of a single approach. If strength training alone can improve multiple deficits seen in patients with CAI, it could save time for both clinician and patient. A resistance-band protocol has already been established as an effective strength-training protocol in improving some deficits in people with CAI.[18,24,25] Therefore, the purpose of our study was to compare the effects of resistance-band (RBP) and PNF protocols on strength, dynamic balance, functional performance, and perceived instability in individuals with CAI.

METHODS

Participants

A total of 55 people with CAI from a local university community (Bloomington, IN) volunteered for this study. Chronic ankle instability was determined by the Identification of Functional Ankle Instability Questionnaire, which is an accurate tool for identifying individuals with CAI.[34] Volunteers qualified if they had a score of 11 or more.[34] If both ankles qualified, the ankle with the highest score (ie, the most severely affected ankle) was considered the involved limb. Volunteers did not qualify if they had pain or swelling in the ankle, had participated in formal rehabilitation within the past 3 months, had a history of lower extremity surgery or fracture in the involved limb, or had any diagnosed neurologic dysfunction, such as multiple sclerosis, Parkinson disease, or head injury. To estimate the appropriate sample size, we conducted a power analysis before the study. The α level was set a priori at $P = .05$, and power was set at 80%. Effect size was estimated at 1.23, which was calculated based on previous strength literature.[18,35] Results of the power analysis indicated that 12 participants per group would provide sufficient power.

Participants were excluded after beginning the study if they developed a nonrelated lower extremity injury or were noncompliant. Compliance was determined by the number of rehabilitation sessions attended. Participants were excluded if they attended less than 80% of the 18 sessions. The final number of participants was 39 (71%). Further articulation of participant flow is shown in Figure 1. Descriptive data for each group are available in Table 1. Before the study began, all participants read and signed an informed consent form approved by the University's Institutional Review Board for the Protection of Human Participants, which also approved the study.

Procedures

Each participant performed baseline testing for isometric strength, dynamic balance, functional performance, and perceived instability for the involved limb only. Testing order of the variables was counterbalanced using a counterbalanced matrix. Immediately after the baseline testing, each participant was sequentially allocated by the researcher (E.A.H.) to 1 of 3 groups in a 1:1:1 ratio: the RBP group, the PNF group, or the control (CON) group. Those in the RBP and PNF groups participated in their assigned treatment protocol 3 times/wk for 6 weeks. Each person met individually with the investigator and progressed at the same rate to allow consistency among participants. After 6 weeks, posttest measures for strength, dynamic balance, functional performance, and perceived instability were tested in all participants. Those in the CON group participated only in the pretest and posttest. All testing and rehabilitation sessions were performed in the athletic training research laboratory.

Strength Testing. An isometric handheld dynamometer (Manual Muscle Testing System; Lafayette Instruments Co, Lafayette, IN) was used to assess strength. The instrument was calibrated before each participant was tested. Four directions were tested: dorsiflexion, plantar flexion, inversion, and eversion. Participants were placed in subtalar neutral position for all testing. The lower leg was strapped down to stabilize and prevent any accessory movement. *Subtalar neutral position* was identified by the congruency method, in which the foot is neither supinated nor pronated and the examiner palpates the equally prominent positions of the medial and lateral aspects of the talus.[36] The participant's positions were different for each direction, as shown in Figure 2. The handheld dynamometer was placed at the superior aspect of the metatarsal heads, depending on the positioning of the foot. Participants were instructed to pull or push against the device as hard as they could for each direction, and the investigator counteracted that force with both hands for 3 seconds per trial. All manual muscle-testing movements and positions were consistent with procedures outlined by Daniels and Worthingham.[37] Three consecutive trials were

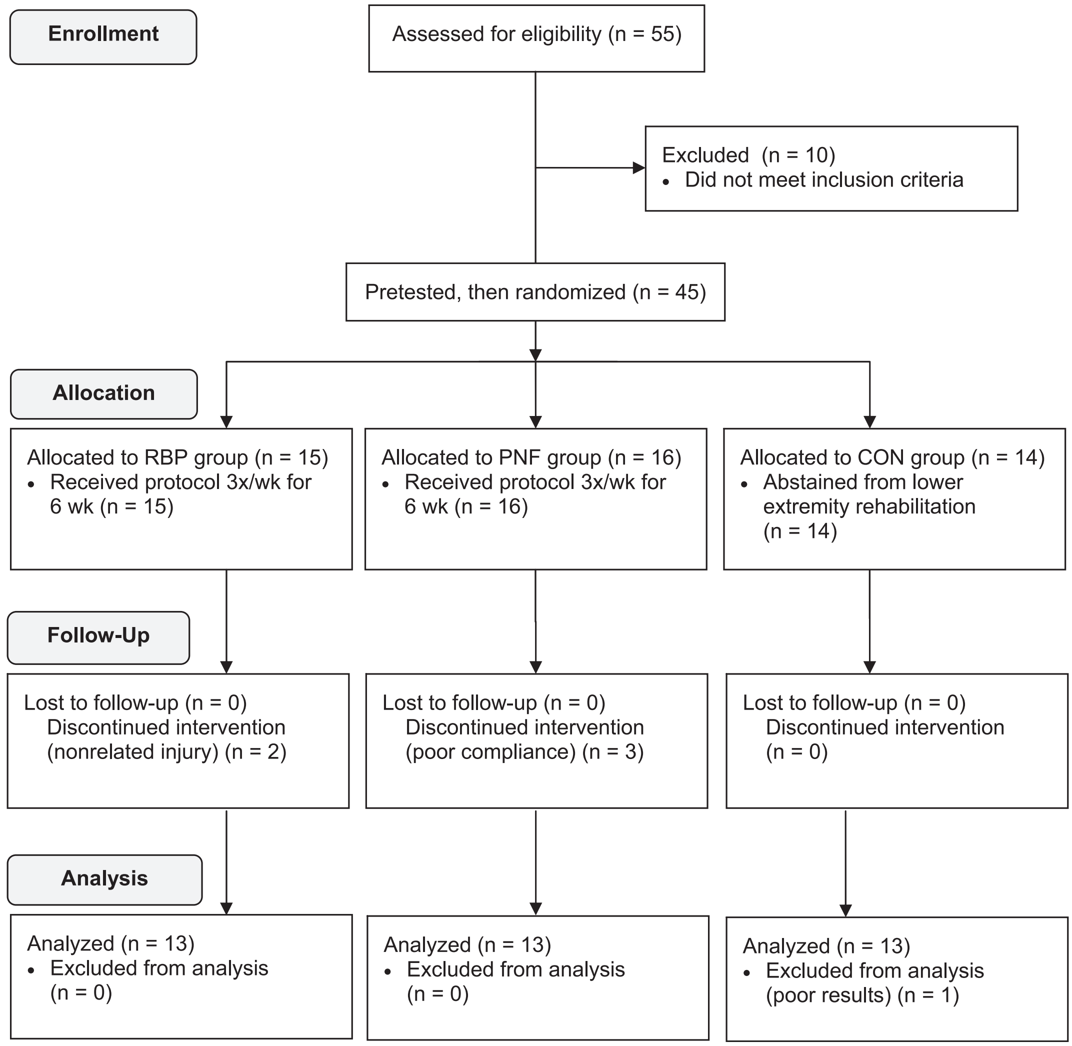

Figure 1. Participant flow diagram. Abbreviations: RBP, resistance-band protocol; PNF, proprioceptive neuromuscular facilitation; CON, control.

conducted, with a 10-second rest between trials. The maximum force (newtons) was used for analysis as the participant's peak force.

Functional Performance Testing. Functional performance testing included the figure-8 hop and the triple-crossover hop tests. The figure-8 hop test evaluates speed and agility,[10] whereas the triple-crossover hop test for distance is an assessment of power. The figure-8 hop test (intraclass correlation coefficient [ICC] = 0.98) was performed by having participants hop in a 5-m course around the cones in an "8" design on the involved ankle (Figure 3A). The participants were instructed to hop as quickly as possible twice through the course. If the right ankle was being tested, then he or she started on the left side and finished on the right side. If the left ankle was being tested, he or she began on the right and finished on the left. Speed was timed in seconds with an electric timer (Speedtrap 2; Brower Timing Systems, Draper, UT). The fastest time was used for analysis.

The modified triple-crossover hop (ICC = 0.95) for distance was measured in centimeters using a cloth tape measure. Although previous researchers[11] found the original test was unable to detect functional performance deficits in those with CAI, we modified the test to increase lateral stress at the ankle. The modification required the participant to hop in a lateral, medial, lateral pattern. The participant stood on the involved leg and hopped 3 times as far as he or she could in a zigzag fashion over a 15-cm tramline (Figure 3B). If the involved limb was on the right side, then he or she started on the left side of the line and vice versa for the left limb. The distance was measured from the starting point to the location of the great toe on the last hop. The trial with the maximum distance was used for analysis.

Dynamic Balance Testing. Proprioception was dynamically tested using the Y-Balance test (FunctionalMovement.com; Functional Movement Systems, Danville, VA). The Y-Balance test was reliable (composite ICC = 0.89)[38] in the measurement of individual reach directions: anterior, posteromedial, and posterolateral. The orientation of the reach direction is relative to the stance limb. Participants stood on the involved limb with the great toe behind the line on the platform located at the center of the 3 diverging lines. Measurements were taken as the participant

Table 1. Participants' Demographic Information

Group	Mean ± SD					No.				
	n	Age, y	Height, cm	Weight, kg	IdFAI Score	Compliance Sessions, Median	Limb, Right/Left	CAI, Unilateral/Bilateral	Sex, Men/Women	Previous Rehabilitation? Yes/No
Resistance-band protocol	13	19.7 ± 2.2	172.9 ± 12.8	69.1 ± 13.5	21.7 ± 3.4	18	9/4	7/6	5/8	7/6
Proprioceptive neuromuscular facilitation	13	18.9 ± 1.3	172.5 ± 5.9	72.7 ± 14.6	21.9 ± 2.7	17	11/2	5/8	5/8	8/5
Control	13	20.5 ± 2.1	175.2 ± 8.1	70.2 ± 11.1	20.4 ± 3.7	N/A	6/7	8/5	7/6	5/8

Abbreviations: CAI, chronic ankle instability; IdFAI, Identification of Functional Ankle Instability.

pushed the target plate along the polyvinyl chloride pipe with the opposite leg. The participant returned to the starting position without losing balance after each trial. One to 4 practice trials were performed for each direction, so the participant became comfortable performing the task. For testing, the participant performed 3 consecutive trials in 1 direction. After each trial, the examiner recorded the distance indicated by the target plate and then returned it to the center so the participant could perform the next trial. The maximum distance (centimeters) for each reach direction was recorded. The participant had a 30-second rest before moving on to the next direction. Reach distances were normalized to the participant's leg length, which was measured in centimeters from the anterior-superior iliac spine to the distal tip of the medial malleolus. The composite score (percentage) was calculated by taking the average of the 3 maximal reaches divided by the participant's limb length, multiplied by 100. That value was used for statistical analysis.

Perceived Ankle Instability. Perceived ankle instability was measured using the visual analog scale (VAS). Participants were asked to rate their overall perceived ankle instability at that moment by marking a dash across a vertical 10-cm line. This process was completed at baseline and then again after the 6-week protocol.

Rehabilitation Procedures

The RBP Group. Sessions for the RBP group occurred 3 times/wk for 6 weeks under the supervision of the researcher (E.A.H.). The procedures were based on a 6-week rubber-tubing protocol developed by Docherty et al.[18] However, rubber-resistance bands (Mini-bands; SPRI Products, Inc, Libertyville, IL) were used instead of tubing to maintain consistent positioning of the bands on the foot. Participants sat on the floor with 1 end of the band wrapped around a treatment table and the other end around the metatarsal heads of the involved foot. Exercises were performed in 4 directions: dorsiflexion, plantar flexion, inversion, and eversion. With the participant in a long sitting position and knees fully extended, a bolster was placed at about midgastrocnemius level to allow the full range of motion for dorsiflexion and plantar flexion. Inversion and eversion were performed in a modified, long sitting position; the knee of the involved limb flexed, using the heel as a fulcrum, as the participant moved the foot in and out, respectively. The band was stretched to an additional 70% of its resting length to allow for consistent resistance tension among participants.[18,21] Participants were instructed to use only the involved ankle joint and to maintain a consistent pace of approximately 3 to 5 seconds per repetition throughout the full range of motion. Each week, participants progressed by increasing the number of sets, band resistance, or both (Table 2).[18] Participants completed all 4 directions before moving on to the next set.

The PNF Group. The PNF strength group met at the same intervals as the RBP group. This group used the slow-reversal PNF technique, which involves a concentric contraction of the antagonist muscle, followed by a concentric contraction of the agonist muscle.[29] The participants were in a long sitting position with the ankle extended over the end of the table. The lower leg was stabilized at the knee by the investigator to prevent any movements at the knee and hip. The participants were

Figure 2. Positions for isometric testing using the handheld dynamometer (Manual Muscle Testing System; Lafayette Instruments Co, Lafayette, IN). A, Dorsiflexion, B, plantar flexion, C, inversion, and D, eversion.

instructed on how to perform 2-diagonal patterns. The D1 pattern consisted of 2 phases: dorsiflexion-inversion (up and in) and plantar flexion-eversion (down and out). The D2 pattern consisted of 2 phases: dorsiflexion-eversion (up and out) and plantar flexion-inversion (down and in). Manual resistance was applied by the investigator (E.A.H.) to the distal aspect of the foot at the metatarsal heads. Participants were told to provide maximal effort for each repetition. Maximal counteracting resistance during each phase of the diagonal pattern was applied throughout the entire range of motion of the isotonic contraction at a moderate speed, taking approximately 3 to 5 seconds to complete. At the end of the range, the investigator changed hand position to complete the other phase of the diagonal pattern. There was a 60-second rest between sets but no rest between repetitions. The protocol progression is shown in Table 2.

The CON Group. Members of the control group avoided any new strength or rehabilitative exercises for their ankles during the 6 weeks between the pretest and posttest procedures. They were allowed to participate in regular activities.

Statistical Analysis

For strength, dynamic balance, and functional performance, we used the maximum of 3 test trials for statistical analysis. Two multivariate, repeated-measures analyses of variance were conducted: 1 for the isometric strength measures (dorsiflexion, plantar flexion, inversion, and eversion) and another for the functional performance (figure-8 hop and triple-crossover hop), dynamic balance, and perceived ankle instability variables. If a finding was significant, follow-up univariate analyses were conducted on each dependent variable individually. The univariate analyses included one within-subject factor (time at 2 levels: pretest, posttest) and one among-subjects factor (group at 3 levels: RBP, PNF, CON). Finally, a Tukey post hoc test was used to identify any specific differences. The a priori α level was set at $P < .05$.

We also calculated minimum detectable change for each dependent variable based on data collected from the control

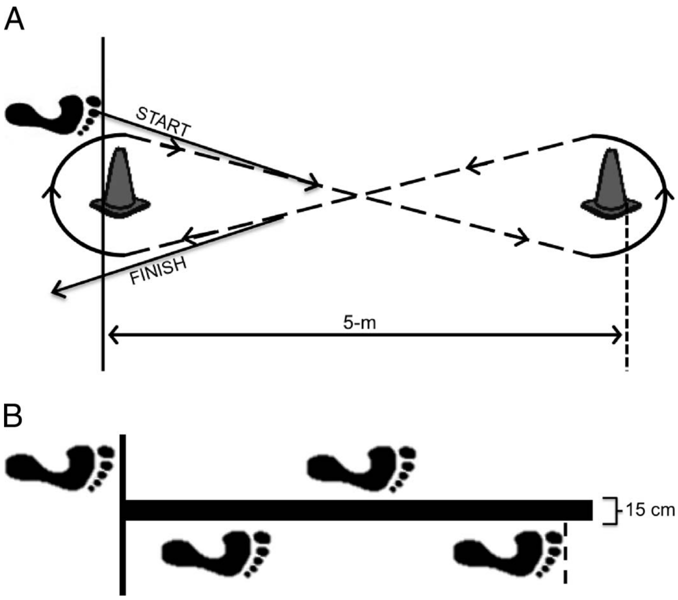

Figure 3. A, Figure-8 hop test for time is a single-legged hop twice around the course. B, Triple-crossover hop is a distance test. Both A and B show testing of the right foot.

group, which allowed us to determine whether any changes in the rehabilitation groups were greater than the error that can be expected with that measure. Additionally, effect sizes were calculated using the bias-corrected Hedges *g* with the corresponding 95% confidence intervals.[39] Effect sizes were interpreted as *weak* ($\leq$0.39), *moderate* (0.40–0.69), or *strong* ($\geq$0.70).[40]

RESULTS

Means, standard deviations, and minimum detectable change scores for all dependent variables are shown in Table 3. Effect sizes and 95% confidence intervals for the dependent variables are displayed in Table 4.

Strength Outcomes

We observed a significant time-by-group interaction (Wilks $\lambda = 0.69$, $F_{2,36} = 7.96$, $P = .01$, $\eta^2 = 0.31$, power $= 0.94$). In the following paragraphs, we report the findings of the univariate analyses, followed by a Tukey post hoc test for any significant differences.

Plantar-flexion and dorsiflexion strength resulted in a significant time-by-group interaction ($P = .04$). In both directions, only the RBP group improved after the 6-week strength protocol ($P < .05$). However, results in the plantar-flexion direction should be interpreted with caution. In the RBP group, the mean difference between the pretest and posttest was smaller than the calculated minimum detectable change (40.1 versus 51.5 N, respectively), and the resultant effect size was weak (0.3). Neither the PNF nor CON group improved from pretest to posttest in either the plantar-flexion or dorsiflexion directions ($P > .05$).

Inversion and eversion strength also resulted in a significant interaction ($P = .01$). Both the RBP and the PNF groups improved after the intervention ($P < .05$). The CON group did not differ between pretest and posttest ($P > .05$).

Table 2. Resistance-Band and Proprioceptive Neuromuscular Facilitation Rehabilitation Protocols

	Protocol		
	Resistance-Band		Proprioceptive Neuromuscular Facilitation
Week	Resistance	Sets × Repetition	Sets × Repetition
1	Heavy (light blue)	3 × 10	2 × 10
2	Heavy (light blue)	4 × 10	2 × 15
3	Super heavy (dark blue)	3 × 10	3 × 10
4	Super heavy (dark blue)	4 × 10	3 × 15
5	Ultra heavy (purple)	3 × 10	4 × 10
6	Ultra heavy (purple)	4 × 10	4 × 15

Functional Outcomes

A significant time-by-group interaction for the function-dependent variables was noted (Wilks $\lambda = 0.82$, $F_{2,36} = 3.89$, $P = .03$, $\eta^2 = 0.18$, power $= 0.67$). In the following paragraphs, we report the findings of the univariate analyses.

For the figure-8 hop test, we identified a significant time-by-group interaction ($F_{2,36} = 3.64$, $P = .04$). The post hoc test showed both the RBP and PNF groups improved from pretest to posttest ($P < .05$), whereas the control group did not improve ($P > .05$). Despite achieving statistical significance, the pretest to posttest effect size for both RBP and PNF groups was weak to moderate with the 95% confidence intervals encompassing 0. Therefore, the clinical meaningfulness of the improvement was minimal. The triple-crossover hop test also identified a significant time-by-group interaction ($F_{2,36} = 3.58$, $P = .04$). However, the Tukey post hoc test indicated that none of the groups improved from pretest to posttest ($P > .05$). The composite Y-Balance test did not demonstrate a significant time-by-group interaction ($F_{2,36} = 2.71$, $P = .08$). None of the groups improved from pretest to posttest. Finally, for the VAS, we found a significant time-by-group interaction ($F_{2,36} = 5.12$, $P = .01$). The RBP and PNF groups improved from pretest to posttest ($P < .05$). No difference was identified in the CON group ($P > .05$).

DISCUSSION

The primary finding of our study was that both strength-training protocols were effective in improving strength and perceived ankle instability. Interestingly, even with these strength gains and the patients' reports of greater stability in the ankle, improvements in functional performance and dynamic balance were limited.

Isometric Strength

Isometric ankle strength increased after both rehabilitation protocols—the RBP and PNF. Previous authors[18,24,25] who evaluated strength-training protocols observed strength improvement, except for 1 group[21] that reported no improvement. Each study used a slightly different protocol, such as the resistance-tubing progressive training protocol,[18,21,25] the multiaxial ankle exerciser,[25] or the isokinetic dynamometer,[24] but significant improvement in ankle strength was obtained with all techniques if adequate resistance was applied. We slightly adapted the resistance-tubing progressive training protocol developed by Docherty

Table 3. Raw-Data Values by Group and Test

Test	Resistance Band Pretest	Resistance Band Posttest	Proprioceptive Neuromuscular Facilitation Pretest	Proprioceptive Neuromuscular Facilitation Posttest	Control Pretest	Control Posttest	Minimum Detectable Change[a]
	Group, Mean ± SD						
Isometric strength, N							
Dorsiflexion	215.8 ± 62.0	265.8 ± 37.4[b]	237.0 ± 62.3	259.3 ± 50.8	261.5 ± 60.3	255.4 ± 67.0	35.5
Plantar flexion	265.4 ± 50.0	305.5 ± 36.3[b]	282.8 ± 44.6	299.7 ± 34.0	274.6 ± 45.2	267.2 ± 50.4	51.5
Inversion	157.2 ± 48.2	202.9 ± 37.4[b]	166.0 ± 51.0	212.6 ± 44.4[b]	187.5 ± 57.4	188.2 ± 47.2	24.3
Eversion	147.8 ± 41.2	189.6 ± 26.9[b]	141.2 ± 34.0	183.9 ± 27.9[b]	175.5 ± 41.7	176.0 ± 43.0	21.8
Functional performance							
Figure-8 hop, s	10.7 ± 1.7	10.1 ± 1.2[b]	11.2 ± 1.8	10.2 ± 1.5[b]	10.4 ± 1.9	10.3 ± 1.9	0.8
Triple-crossover hop, cm	455.5 ± 96.4	480.4 ± 84.6	451.1 ± 108	479.2 ± 95.1	519.7 ± 150	509.6 ± 120	45.6
Y-Balance (% normalized to limb length)							
Composite	97.4 ± 7.2	102.0 ± 7.2	96.9 ± 7.0	101.5 ± 7.2	99.6 ± 7.7	99.9 ± 4.6	7.7
Perceived ankle instability							
Visual analog scale, cm	4.2 ± 1.9	2.3 ± 1.2[b]	4.3 ± 1.5	2.8 ± 0.9[b]	4.8 ± 2.2	4.9 ± 2.2	1.6

[a] Calculated from data for the control group.
[b] Statistically significant ($P < .05$) improvement from pretest to posttest.

et al[18] using resistance bands instead of resistance tubing to avoid the tubing rolling off the foot and affecting the results. Our findings are consistent with those of previous resistance-tubing progressive training protocol studies in demonstrating improvements in dorsiflexion,[18] inversion,[25] and eversion.[18,25]

Previous researchers[33] also concluded that lower extremity PNF strength patterns were effective at increasing hamstrings strength at the knee; however, no outcomes were reported at the ankle. In the present study, the PNF group improved inversion strength by 28% and eversion strength by 31%. In the dorsiflexion and plantar-flexion directions, no meaningful strength improvements (9% and 6%, respectively) were identified. We hypothesize that the investigator could not provide adequate manual resistance in those directions during the PNF pattern to elicit a change.

Therefore, when the goal of the rehabilitation protocol is to improve plantar-flexion strength, greater resistance is necessary than was provided in either of these protocols. Clinicians should consider using closed kinetic chain exercises or open kinetic chain exercises that provide greater resistance to improve plantar flexion.

Dynamic Balance and Functional Performance

Neither rehabilitation protocol had a clinical effect on dynamic balance or functional performance as measured by the figure-8 hop test, the triple-crossover hop test, and the Y-Balance test, which was surprising. Based on previous research,[13,18,25,32,33] we hypothesized that with improvements in strength, improvements in balance and functional performance would follow. However, that was not the case in our study. We believe our findings conflict with those of previous investigators for several reasons. First, our measures were more dynamic and required coordination of the entire lower extremity. Earlier authors focused their testing more specifically at the ankle, including simple measures such as ankle-joint position sense[18] and single-legged balance.[24] Subsequently, both their training protocols and testing focused solely on the ankle. Our training protocols were localized to the ankle, but our testing included more advanced, dynamic tasks, which required coordination of the hip, knee, and ankle. Second, the lack of improvement in Y-Balance scores with either rehabilitation protocol conflicts with the findings of an earlier study that used a multicomponent rehabilitation protocol[20] that

Table 4. Effect Sizes (95% Confidence Intervals) by Group and Test[a]

Test	Resistance Band	Proprioceptive Neuromuscular Facilitation	Control
	Group		
Isometric strength			
Dorsiflexion	0.9[b] (0.1, 1.7)	0.4 (−0.4, 1.1)	−0.1 (−0.9, 0.7)
Plantar flexion	0.3 (0.03, 1.6)	0.4 (−0.4, 1.2)	−0.2 (−0.9, 0.6)
Inversion	1.0[b] (0.1, 1.8)	0.9[b] (0.1, 1.7)	−0.1 (−0.8, 0.8)
Eversion	1.1[b] (0.3, 1.9)	1.2[b] (0.4, 2.1)	0.01 (−0.8, 0.8)
Functional performance			
Figure-8 hop	0.4 (−0.4, 1.1)	0.5 (−0.2, 1.3)	0.1 (−0.7, 0.8)
Triple-crossover hop	0.3 (−0.5, 1.0)	0.3 (−0.5, 1.0)	−0.1 (−0.8, 0.7)
Y-Balance			
Composite	0.6 (−0.2, 1.4)	0.6 (−0.2, 1.4)	0.1 (−0.7, 0.8)
Perceived ankle instability			
Visual analog scale	1.1[b] (0.3, 1.9)	1.1[b] (0.3, 1.9)	−0.1 (−0.8, 0.7)

[a] Effect size was calculated using Hedges *g*.
[b] Clinical significance from pretest to posttest.

resulted in significant improvements in Star Excursion Balance Test scores. However, it is likely that the improvements seen in that study stemmed from the balance exercises included in that protocol, rather than the strengthening exercises. Previous studies identified functional performance improvements after isokinetic strength training[24] and PNF strength training.[32] However, when evaluating those data further, it appears that the clinical significance of the results might be questioned because of weak to moderate effect sizes and 95% confidence intervals crossing 0.

We conclude that strength-training protocols alone did not effectively target the neuromuscular systems in the entire lower extremity. To generate improvement in dynamic tasks, such as the triple-crossover hop and the Y-Balance tests, rehabilitation strategies may require greater emphasis on knee and hip neuromuscular control. Therefore, we suggest that a strengthening program focusing on the entire lower extremity, not just the ankle, may improve performance on these dynamic balance and functional tasks.

Perceived Ankle Instability

It is important to evaluate not only physical measures after a rehabilitation protocol but also the patient's perceived improvements. Using the VAS, patients in both rehabilitation protocols noted improvements in perceived ankle instability during the 6 weeks. The RBP and PNF groups had 1.8-cm and 1.6-cm improvements, respectively, which we consider a clinically meaningful change. Previous researchers[41] reported that a 1.3-cm change in pain severity using a VAS was clinically significant, corresponding with our study, which identified a minimum detectable change of 1.6 cm and a strong effect size for each treatment group (1.1). The use of a VAS provides important patient-reported outcomes to clinicians, which can be viewed as evidence of the effectiveness of the rehabilitation protocols. In this study, we found that both rehabilitation protocols gave participants an improved sense of ankle stability.

Future Research

Future investigators should evaluate the effectiveness between local (single-joint) and global (multijoint) PNF patterns by focusing not only on the ankle but on the entire lower extremity. That would determine whether more deficits are improved while saving the clinician time and energy. Long-term follow-up testing would identify the lasting effects of each rehabilitation protocol. Anecdotally, participants stated that, overall, their ankles "felt better," and they noticed fewer episodes of "giving way." Strength-training and multicomponent rehabilitation studies should continue to use clinically applicable dependent variables to improve rehabilitation protocols and better serve the patient and clinician. Calculating effect sizes in the statistical analyses will help determine whether rehabilitation protocols are clinically relevant.

CONCLUSIONS

Chronic ankle instability is a multifaceted condition; therefore, a multifaceted rehabilitation approach is necessary to attain the desired functional outcomes. In our study, both the RBP and PNF groups improved in isometric strength and perceived ankle instability. Interestingly, participants in both rehabilitation groups reported their ankles felt more stable after rehabilitation. From the results of this study, it appears that additional exercises are required to improve dynamic balance and functional performance in patients with ankle instability.

Although the RBP is common in ankle rehabilitation, the PNF protocol should be identified as an effective treatment as well for improving strength in individuals with CAI. Of course, as with any rehabilitation protocol, those decisions should be based on the specific goals and objectives being addressed.

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Address correspondence to Emily A. Hall, MS, LAT, ATC, School of Public Health, Indiana University, C200, 1025 East 7th Street, Bloomington, IN 47405. Address e-mail to emahall@indiana.edu.