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A 4-Week Multimodal Intervention for Individuals With Chronic Ankle Instability: Examination of Disease-Oriented and Patient-Oriented Outcomes

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Context: Individuals with chronic ankle instability (CAI) experience disease- and patient-oriented impairments that contribute to both immediate and long-term health detriments. Investigators have demonstrated the ability of targeted interventions to improve these impairments. However, the combined effects of a multimodal intervention on a multidimensional profile of health have not been evaluated.

Objective: To examine the effects of a 4-week rehabilitation program on disease- and patient-oriented impairments associated with CAI.

Design: Controlled laboratory study.

Setting: Laboratory.

Patients or Other Participants: Twenty adults (5 males, 15 females; age = 24.35 ± 6.95 years, height = 169.29 ± 10.10 cm, mass = 70.58 ± 12.90 kg) with self-reported CAI participated. Inclusion criteria were at least 1 previous ankle sprain, at least 2 episodes of "giving way" in the 3 months before the study, and a Cumberland Ankle Instability Tool score ≤24.

Intervention(s): Individuals participated in 12 sessions over 4 weeks that consisted of ankle stretching and strengthening, balance training, and joint mobilizations. They also completed home ankle-strengthening and -stretching exercises daily.

Main Outcome Measure(s): Dorsiflexion range of motion (weight-bearing–lunge test), isometric ankle strength (inversion, eversion, dorsiflexion, plantar flexion), isometric hip strength (abduction, adduction, flexion, extension), dynamic postural control (Y-Balance test), static postural control (eyes-open and -closed time to boundary in the anterior-posterior and medial-lateral directions), and patient-reported outcomes (Foot and Ankle Ability Measure–Activities of Daily Living and Foot and Ankle Ability Measure–Sport, modified Disablement in the Physically Active scale physical and mental summary components, and Fear-Avoidance Beliefs Questionnaire–Physical Activity and Fear-Avoidance Beliefs Questionnaire–Work) were assessed at 4 times (baseline, preintervention, postintervention, 2-week follow-up).

Results: Dorsiflexion range of motion, each direction of the Y-Balance test, 4-way ankle strength, hip-adduction and -extension strength, the Foot and Ankle Ability Measure–Activities of Daily Living score, the modified Disablement in the Physically Active scale–physical summary component score, and the Fear-Avoidance Beliefs Questionnaire–Physical Activity score were improved at postintervention ($P < .001$; effect-size range = 0.72–1.73) and at the 2-week follow-up ($P < .001$; effect-size range = 0.73–1.72) compared with preintervention. Hip-flexion strength was improved at postintervention compared with preintervention ($P = .03$; effect size = 0.61). Hip-abduction strength was improved at the 2-week follow-up compared with preintervention ($P = .001$; effect size = 0.96). Time to boundary in the anterior-posterior direction was increased at the 2-week follow-up compared with preintervention ($P < .04$; effect-size range = 0.61–0.78) and postintervention ($P < .04$) during the eyes-open condition.

Conclusion: A 4-week rehabilitation program improved a multidimensional profile of health in participants with CAI.

Key Words: dorsiflexion, postural control, self-reported function, manual therapy, balance training, strength

Key Points

- After a 4-week multimodal rehabilitation program that incorporated ankle stretching and strengthening, balance training, and joint mobilizations, individuals with chronic ankle instability demonstrated improved dorsiflexion range of motion, dynamic postural control, ankle strength, hip strength, ankle-specific function, global wellbeing, and fear-avoidance beliefs.
- Improvements were identified immediately postintervention and were maintained at 2 weeks after program completion; static postural-control improvements were identified only at the 2-week follow-up and in the eyes-open condition.
- Large effect sizes and improvements that exceeded the minimal detectable change of the measures indicated that these changes were not only statistically significant but may also have been clinically meaningful.
- This evidence supports the incorporation of a multifaceted evidence-based intervention to enhance a multidimensional profile of health in the treatment of patients with chronic ankle instability.

Ankle sprains account for 10% to 30% of all athletic injuries.[1] Whereas some patients successfully recover from ankle-sprain injuries, 40% will develop *chronic ankle instability* (CAI),[2] which is a condition characterized by residual ankle-sprain symptoms, repetitive ankle sprains, and recurrent instability.[3] In addition to repeated bouts of acute trauma, CAI has been associated with an increased risk of posttraumatic ankle osteoarthritis, deficits in health-related quality of life (HRQOL), and decreased physical activity levels.[4–6] The immediate and long-term consequences of CAI highlight the need to develop interventions that address this complex and multifaceted condition.

Several impairments contribute to the residual symptoms, functional loss, and decreased HRQOL associated with CAI. These deficits have been identified through a combination of disease-oriented measures that examine local joint stability and motor coordination. For example, dorsiflexion range of motion (DROM) is one of the most commonly cited deficits among individuals with CAI.[7] The DROM restrictions are also associated with dynamic postural-control impairments,[8] another frequent deficit in those with CAI.[9,10] Furthermore, static postural-control deficits suggest a general decrease in postural control in this population.[9,10] Finally, alterations in both distal[11] and proximal[12] muscular strength have been identified. The wide range of impairments identified in these individuals has revealed that CAI is not associated merely with 1 factor, such as diminished proprioception, postural control, or ligamentous laxity. Rather, individuals with CAI display multiple impairments, which may contribute to the development and progression of this condition. Therefore, effective rehabilitation may need to incorporate a range of strategies to target an assortment of potential CAI impairments.

In the literature, authors of most intervention studies have used a focused intervention, primarily targeted at 1 or more of the aforementioned impairments.[9–11] For example, isolated joint-mobilization interventions have primarily improved DROM, as well as postural control.[8,13,14] Balance-training programs have resulted in improved static and dynamic postural control.[15,16] Ankle-strengthening programs have improved ankle strength.[17] Furthermore, many of these focused interventions have also demonstrated the ability to enhance ankle-specific patient-reported outcomes (PROs).[18] The success of focused interventions in targeting specific CAI-related impairments while also improving other contributing factors, including self-reported function, suggests that a rehabilitation strategy combining several of these protocols may concurrently address many common CAI impairments (eg, range of motion [ROM], postural control, strength). Furthermore, combining protocols may create synergy that could produce even stronger treatment effects.

Researchers[19–21] have investigated rehabilitation protocols that combine at least 2 interventions and have identified improvements in postural control, DROM, and self-reported ankle function. Whereas these studies were more comprehensive because the researchers examined combinations of stretching, balance training, strength training, and other intervention modalities, many did not incorporate previously established CAI intervention protocols, which have demonstrated improvements in both disease- and patient-oriented outcomes, or incorporate both supervised- and home-intervention portions.[18] Furthermore, these investigators did not evaluate a comprehensive battery of CAI-associated impairments (eg, ROM, strength, balance, self-reported function). Finally, these authors have evaluated ankle-specific self-reported function, but changes in overall health and fear of reinjury have not been thoroughly evaluated after an intervention.[4] Cumulatively, these studies have demonstrated that many rehabilitation strategies can improve a collection of common impairments associated with CAI. However, it remains unclear whether a multimodal program that includes a diverse collection of previously established intervention protocols, as well as both supervised- and home-intervention components, will lead to improvements across the spectrum of CAI impairments that include both disease- and patient-oriented outcomes. Therefore, the purpose of our study was to examine the effects of a 4-week rehabilitation program incorporating multiple evidence-based interventions that have been established in the literature as addressing common CAI impairments (ROM, strength, and balance), disease-oriented impairments, and patient-oriented impairments associated with CAI. Specifically, we aimed to build on the literature by evaluating changes in the multidimensional profile of disease- and patient-oriented impairments that include DROM, ankle and hip strength, and postural control, as well as self-reported ankle function, global well-being, and injury-related fear. We hypothesized that the rehabilitation program would result in statistically significant and clinically relevant improvements in DROM, isometric ankle and hip strength, dynamic and static postural control, and self-reported ankle function.

METHODS

Design

For this controlled laboratory study, we examined the effects of a 4-week multimodal intervention on disease- and patient-oriented outcomes in patients with CAI. All participants completed 4 data-collection sessions (baseline, preintervention, postintervention, 2-week follow-up) and a 4-week intervention, which consisted of 12 supervised sessions and a daily home-exercise protocol (Figure 1). The independent variable was time (baseline, preintervention, postintervention, and 2-week follow-up). Disease-oriented dependent variables were DROM, 4-way isometric ankle and hip strength, and dynamic and static single-limb postural control. Patient-oriented dependent variables were scores on the Foot and Ankle Ability Measure–Activities of Daily Living (FAAM-ADL), Foot and Ankle Ability Measure–Sport (FAAM-Sport), modified Disablement in the Physically Active (mDPA) scale, and the Fear-Avoidance Beliefs Questionnaire (FABQ).

Participants

A total of 22 participants with self-reported CAI (5 males, 15 females; age = 24.91 $\pm$ 7.33 years, height = 169.18 $\pm$ 9.66 cm, mass = 70.62 $\pm$ 12.27 kg) volunteered for the study. Of the 22 enrolled individuals, 20 completed the study, and their data were included in the analysis. Two individuals withdrew during the intervention phase due to non–study-related reasons. Baseline characteristics of the

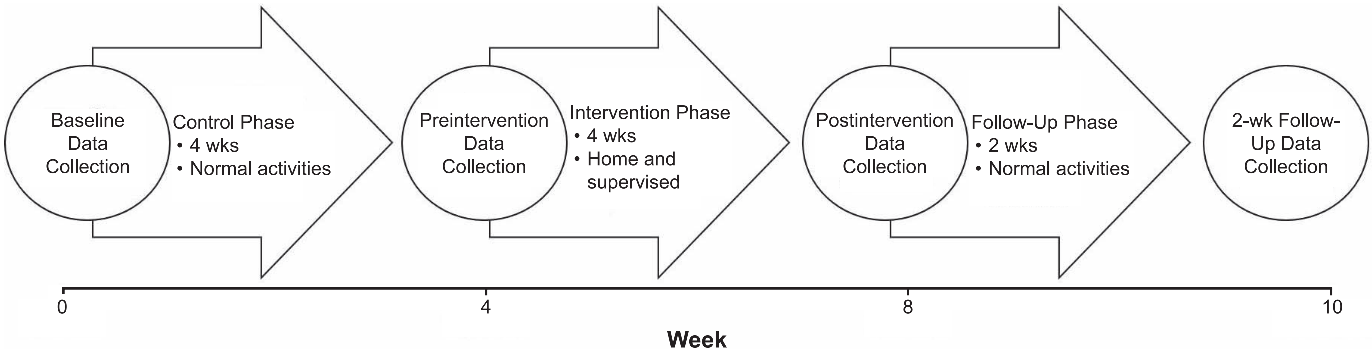

Figure 1. Study timeline representing 4 data-collection sessions (baseline, preintervention, postintervention, 2-week follow-up) and the phases of the intervention (control, intervention, follow-up).

included participants are presented in Table 1. Participants were recruited via electronic and poster advertisements at a large public university over a 4-month period. Individuals were included if they were physically active ($\geq$24 on the Godin Leisure-Time Exercise Questionnaire) adults (age range = 18–45 years) with a history of $\geq$1 ankle sprain at least 6 months before the study and $\geq$2 episodes of "giving way" in the 3 months before the study. Participants also had to answer *yes* to at least 5 questions on the Ankle Instability Instrument and score $\leq$24 on the Cumberland Ankle Instability Tool. In participants with bilateral CAI, data from the limb with the lower Cumberland Ankle Instability Tool score were analyzed. Inclusion criteria were based on the International Ankle Consortium position statement.[3] Exclusion criteria consisted of an ankle sprain within the 6 weeks before the study, another lower extremity injury within the 6 months before the study, a history of lower extremity surgery, or any condition that might affect postural control. All participants provided written informed consent, and the study was approved by the Old Dominion University Institutional Review Board.

Sample Size

An a priori power analysis was completed using data from a previous study[19] in which the researchers examined the effects of a similar balance-training program. Based on an α level of .05, a power of 0.95, and an effect size of 0.97 determined by the FAAM-Sport, 16 participants were needed.[19] Therefore, we enrolled 20 participants to account for up to 20% attrition.

Table 1. Participant Demographics and Inclusion Criteria

	No.
Sex, male/female	5/15
Ankle, right/left	9/11
	Mean ± SD
Age, y	24.35 ± 6.95
Height, cm	169.29 ± 10.10
Mass, kg	70.58 ± 12.90
No. of previous ankle sprains	2.95 ± 1.50
No. of episodes of "giving way" in 3 mo before study	5.60 ± 6.54
Time since last sprain, mo	18.50 ± 17.22
Ankle Instability Instrument, No. of *yes* responses	6.85 ± 1.31
Cumberland Ankle Instability Tool score (maximal score = 30)	16.05 ± 5.55
Godin Leisure-Time Exercise Questionnaire score (maximal score = 119)	63.65 ± 25.86

Procedures

Upon enrollment, participants completed the baseline and preintervention data-collection sessions, which were separated by 4 weeks of normal activity. Baseline and preintervention data were used to determine reliability and the minimal detectable change (MDC) for all dependent variables. After the preintervention session, recruits started the 4-week intervention that consisted of both home and supervised components (Appendix). The postintervention data-collection session occurred within 48 hours after the intervention ended. A follow-up session occurred 2 weeks after the postintervention data-collection session (2-week follow-up). Participants were instructed to cease all interventions (home and supervised) during the 2-week period before the follow-up session. During each data-collection session, we administered the patient-oriented outcomes (FAAM-ADL, FAAM-Sport, mDPA, FABQ) before evaluating the disease-oriented outcomes (DROM, isometric hip and ankle strength, and dynamic and static postural control). Patient- and disease-oriented outcomes were collected in a counterbalanced order that was maintained across all data-collection sessions for each participant. One athletic trainer (AT; C.J.P.) with 5 years of experience conducted all data-collection sessions. This investigator did not have access to any previous data during the data-collection sessions.

Dorsiflexion Range of Motion

We used the weight-bearing–lunge test (WBLT) to measure DROM. The WBLT was completed using the knee-to-wall principle in which the involved heel is kept firmly planted on the floor while the participant lunges forward to touch the knee to the wall.[22] The uninvolved limb was placed in a comfortable position that allowed stability to be maintained. When the participant could maintain heel and knee contact, he or she was progressed away from the wall. If heel and knee contact was no longer maintained while lunging, the participant was moved closer to the wall. Maximum DROM was indirectly measured as the distance in centimeters from the great toe to the wall based on the farthest distance the foot could be placed without losing heel and knee contact.[22] Participants performed 1 practice trial and then 3 test trials on the involved limb, which were averaged for analysis. The WBLT has demonstrated high test-retest reliability (intraclass correlation coefficient [ICC] range = 0.80–0.99), an average MDC of 1.9 cm,[22] and improvements after interventions.[8,14,23]

Dynamic Postural Control

Dynamic postural control was measured using the Y-Balance Test (Professional Y-Balance Test Kit; Functional Movement Systems, Inc, Chatham, VA).[24,25] After receiving oral instruction and watching demonstrations, participants stood on the center of the footplate with the great toe of the involved limb at the starting line and hands on hips. While balancing on the involved limb, they reached with the uninvolved limb in the anterior, posteromedial, and posterolateral directions by pushing the indicator box as far as possible. Participants completed 4 practice trials and then 3 test trials in each of the 3 directions. We discarded and repeated test trials if participants did not maintain balance, raised the heel of the stance limb during the trial, removed their hands from their hips, used the reach indicator for support, kicked the indicator, or did not return the uninvolved limb to the starting position.[24,25] Test trials were averaged and normalized to limb length (%) for analysis. The Y-Balance Test has demonstrated high test-retest reliability in the anterior (ICC = 0.93), posteromedial (ICC = 0.91), and posterolateral (ICC = 0.85) directions.[24]

Static Postural Control

One practice and 3 test trials of quiet single-limb stance on a force plate were used to assess static postural control during eyes-open and -closed conditions.[26] Before assessment, each participant's foot was measured and centered on the force plate. We instructed participants to stand quietly with their hands on their hips and their uninvolved limb positioned at 45° of knee flexion and 30° of hip flexion during each 10-second trial. A trial was discarded and repeated if the participant could not maintain the stance position for the entire 10 seconds, touched down, or opened his or her eyes during eyes-closed trials. Center-of-pressure data were separated into anterior-posterior (AP) and medial-lateral (ML) components and analyzed separately as time to boundary (TTB) using custom MATLAB (version R2015a; The MathWorks Inc, Natick, MA) code.[26] The TTB consisted of the mean of TTB minima (TTB MM) and the standard deviation of TTB minima (TTB SD) in both the AP and ML directions, which estimate the time available to make a postural-control correction and the number of solutions available to maintain postural control, respectively. The TTB variables have demonstrated poor to good test-retest reliability (ICC range, 0.34–0.69)[26] and have been responsive to change after intervention.[14]

Isometric Strength

A handheld dynamometer (model MicroFET2; Hogan Health Industries Inc, West Jordan, UT) was used to assess dorsiflexion (DF), plantar flexion (PF), inversion, and eversion isometric strength at the ankle, as well as hip abduction, adduction, flexion, and extension.[27] All procedures were conducted based on methods found to have high test-retest reliability (ICC range, 0.77–0.96).[27] For all strength tests, participants were instructed to "ramp into" a 3-second maximal-effort contraction while the examiner (C.J.P., M.C.H., or an examiner who was not an author) applied unrelenting resistance. Peak forces were recorded to the nearest 0.1 N. For each motion, 1 practice trial and then 3 test trials were recorded; the data were normalized to body weight and averaged for analysis.

Region-Specific Patient-Reported Outcomes

Ankle-specific self-reported function was assessed using the FAAM-ADL and FAAM-Sport instruments. These questionnaires were designed to quantify how foot and ankle conditions affect activity and function.[28] The FAAM-ADL is a 21-item scale for assessing function during activities of daily living. The FAAM-Sport is an 8-item scale that focuses on sport-related activities. The items in both instruments are scored on a 5-point Likert scale ranging from 0 (*no difficulty at all*) to 4 (*unable to do*). Scores are transformed into percentages, with 100% representing *no functional impairments*. The FAAM-ADL (ICC = 0.87) and FAAM-Sport (ICC = 0.89) have demonstrated high test-retest reliability[28] and the ability to identify region-specific deficits in those with CAI.[4]

Generic Patient-Reported Outcomes

The mDPA was used as a generic measure of HRQOL.[29] This PRO was specifically designed to assess overall HRQOL and function in physically active people through 2 subscales: the physical summary component (PSC) and mental summary component (MSC). The 12-item mDPA-PSC addresses impairment, activity limitations, and participation restrictions. The 4-item mDPA-MSC evaluates emotional wellbeing. A 5-point Likert scale ranging from 0 (*no problem*) to 4 (*severe problem*) is used to evaluate each item. Scores for each item are combined to create total scores for each summary component (mDPA-PSC range = 0–48; mDPA-MSC range = 0–16), with higher scores indicating functional limitations and decreased quality of life. The DPA has demonstrated high test-retest reliability (ICC = 0.94) in physically active individuals.[30]

Dimension-Specific Patient-Reported Outcomes

We used the 16-item FABQ to assess fear-avoidance beliefs.[31] The FABQ comprises 2 subscales: physical activity (PA) and work (W). The FABQ-PA consists of 5 items, and the FABQ-W consists of 11 items. Each item is scored on a 7-point Likert scale ranging from 0 (*completely disagree*) to 6 (*completely agree*). Scores range from 0 to 24 on the FABQ-PA and from 0 to 42 on the FABQ-W, with greater scores indicating increased injury-related fear. The FABQ has demonstrated good test-retest reliability (ICC > 0.77)[31] and has been used sparingly in the CAI literature.[4]

Intervention

The 4-week rehabilitation program consisted of home and supervised exercise components for the involved limb. The home intervention was completed daily and involved gastrocnemius-soleus complex stretching and ankle strengthening that required approximately 15 minutes to complete. The supervised component involved 12 sessions in which participants completed talocrural-joint mobilizations, balance training, and ankle strengthening over 30 to 45 minutes. All components of the home and supervised interventions were based on previously established rehabilitation programs for those with CAI.[8,16,17] Participants were reminded and refreshed about the home components during the supervised interventions. Interventions were primarily conducted by 1 AT (C.J.P.) with 5 years of experience. Two ATs (M.C.H., an examiner who was not an author) with 5 to 10 years of experience conducted 1% of all intervention sessions. Before initiating the study, the lead investigator held a training session to promote treatment consistency.

Home Intervention. The gastrocnemius-soleus complex stretching component consisted of three 30-second sets of stretching on a half foam roller with the knee in full extension, as well as in slight flexion.[23] These stretches were selected to target the gastrocnemius and soleus muscles. We instructed participants to hold stretches at the point of mild discomfort. Strengthening exercises for DF, PF, inversion, and eversion of the ankle were completed using elastic resistance bands (TheraBand; The Hygenic Corporation, Akron, OH).[17] The number of sets completed was 3, 4, 3, and 4 for weeks 1, 2, 3, and 4, respectively, with 10 repetitions completed per set.[17] Participants used a blue heavy-resistance band during the first 2 weeks and a black special–heavy-resistance band during the last 2 weeks of the intervention.[17] All participants were provided instructions, demonstrations, a half foam roller, a TheraBand, and an intervention journal before leaving the laboratory after the preintervention data-collection session. The intervention journal was used to track compliance with the home program.

Supervised Intervention. The joint mobilizations consisted of four 2-minute sets of Maitland grade III anterior-to-posterior talocrural joint mobilizations with a 1-minute rest between sets.[8] During the joint-mobilization treatments, participants lay supine with the involved ankle off a plinth. The investigator (C.J.P., M.C.H., or an examiner who was not an author) stabilized the distal tibia and fibula with 1 hand and directed force posteriorly over the talus with the opposite hand. Large-amplitude, 1-second oscillations from the joint's midrange to end range of accessory motion were applied.[8]

The balance-training program consisted of activities designed to challenge single-limb balance after perturbation.[16] We implemented 5 activities that progressively increased in difficulty as participants became proficient at the task. The activities were hop to stabilization, hop to stabilization and reach, hop-to-stabilization box drill, and static single-limb–stance balance activities with eyes open and closed.[16]

Lastly, a slow-reversal proprioceptive neuromuscular facilitation technique local to the ankle comprising concentric contraction of the antagonist muscle followed by a concentric contraction of the agonist muscle was used to strengthen the ankle musculature in the D1 and D2 patterns described by Hall et al.[17] The investigator (C.J.P., M.C.H., or an examiner who was not an author) applied manual resistance and stabilization. Participants completed 3 sets of 10 repetitions during the first through third intervention sessions, 4 sets of 10 repetitions during the fourth through sixth intervention sessions, 3 sets of 15 repetitions during the seventh and eighth intervention sessions, and 4 sets of 15 repetitions during the 9th through 11th intervention sessions.[17]

Statistical Analysis

Missing items for all PROs were replaced with regression imputation. This method involves establishing the estimated relationship between the missing item and the other items within the PRO instrument using regression and the complete data from other participants. For the participants with missing values, the values of nonmissing items within the PRO were input into the regression equation to predict the missing items. If participants missed more than 33% of the items in a PRO, the PRO was removed from the analysis.[32,33]

For each dependent variable, we calculated MDC scores to determine the minimal change required to achieve change beyond the error of the measurements. Intraclass correlation coefficients for clinician-oriented (ICC [2,3]) and patient-oriented (ICC [2,1]) measures and the standard error of measurement (SEM) from the data collected during the baseline and preintervention sessions were used to calculate MDC scores. The formula SEM $\times \sqrt{2}$ was used for MDC calculation.[34]

Dependent variables were grouped based on similarities and confirmed with intervariable correlations for multivariate analysis of variance (MANOVA). The groups were Y-Balance Test directions, ankle-strength directions, hip-strength directions, eyes-open static balance, eyes-closed static balance, and PROs.[21] The MANOVAs were calculated to compare differences over time (preintervention, postintervention, and 2-week follow-up) for each group of dependent variables. When the MANOVA results were different, we performed separate 1-way analyses of variance (ANOVAs) to examine differences over time (preintervention, postintervention, 2-week follow-up). A 1-way ANOVA was also used to examine differences over time for the WBLT. Sidak post hoc comparisons were conducted when we observed main effects or interactions. The α level for all analyses was set a priori at .05. We did not control for multiple comparisons as recommended in a previous review[20] of sports medicine statistical analysis considerations. Standardized-response mean effect sizes (ESs) and corresponding 95% confidence intervals (CIs) were calculated for each dependent variable.[35] A positive ES indicated improvement after the intervention. We interpreted ESs as *weak* ($\leq$0.39), *moderate* (0.40–0.69), or *strong* ($\geq$0.70).[35] Lastly, the determination of the number of responders was assessed for each outcome by comparing the calculated MDCs with the preintervention-to-postintervention change score for each participant.

RESULTS

Intervention Compliance

Overall, the included participants were 91.86% compliant with the home-based intervention. Specifically, they completed, on average, 92.74% of the home stretching and 91.48% of the home strengthening. The lowest individual level of compliance with either portion of the home-based intervention was 74.49%. Overall, the supervised-session completion rate was 97.50%, as all but 2 participants completed all 12 sessions. Of the 2 participants who did not complete all sessions, 1 completed 11 sessions, and 1 completed 7 sessions. Lastly, 1 participant completed a modified balance-training component consisting of only the static balance and reaching components due to muscle soreness and injury-related fear about performing the hopping tasks. Participants who did not complete the entire intervention or completed a modified intervention were included in the analysis, as this reflects clinical practice and an intention-to-treat model.

Missing Items

No data were removed from the analysis for missing more than 33% of the items on a given PRO. The FAAM-ADL was the only PRO with missing data in which 0.71% of the total data and 2.86% or less of a session's data had to be imputed. Overall, 0.22% of all PRO data was imputed using regression imputation.

Main Outcome Measures

Using the Pillai Trace statistic, MANOVA effects of time were identified for isometric ankle strength ($F_{2,18} = 8.69$, $P < .001$), isometric hip strength ($F_{2,18} = 19.44$, $P < .001$), the Y-Balance Test ($F_{2,18} = 30.06$, $P < .001$), the eyes-open TTB ($F_{2,18} = 33.03$, $P < .002$), and the PROs ($F_{2,18} = 10.84$, $P < .001$). We did not identify effects of time for the eyes-closed TTB ($F_{2,18} = 0.49$, $P < .66$). However, we observed ANOVA main effects of time for the WBLT ($F_{1.80,18.20} = 22.62$, $P < .001$), all ankle-strength directions ($F > 6.55$, $P < .004$), all hip-strength directions ($F > 3.78$, $P < .04$), all Y-Balance Test reach directions ($F > 12.02$, $P < .001$), the eyes-open TTB MM-ML ($F_{1.98,18.02} = 3.32$, $P < .047$), the eyes-open TTB MM-AP ($F_{1.92,18.08} = 8.02$, $P < .001$), the eyes-open TTB SD-AP ($F_{1.72,18.28} = 5.62$, $P < .01$), the FAAM-ADL ($F_{1.29,18.71} = 32.18$, $P < .001$), the mDPA-PSC ($F_{1.65,18.35} = 38.33$, $P < .001$), and the FABQ-PA ($F_{1.92,18.08} = 36.85$, $P < .001$). Main effects of time were not identified for the eyes-open TTB SD-ML ($F_{1.83,18.17} = 1.13$, $P = .33$), the FAAM-Sport ($F_{1.14,18.86} = 3.48$, $P = .07$), the mDPA-MSC ($F_{1.18,18.82} = 3.08$, $P = .09$), or the FABQ-W ($F_{1.63,18.37} = 1.99$, $P = .26$).

Improvements both from preintervention to postintervention ($P < .001$) and from preintervention to the 2-week follow-up ($P < .001$) were demonstrated for the WBLT, all ankle-strength directions, hip adduction, hip extension, hip flexion, all Y-Balance Test reach directions, the FAAM-ADL, the mDPA-PSC, and the FABQ-PA. The FAAM-ADL result also improved from postintervention to the 2-week follow-up ($P < .049$). In addition, improvements were identified at 2-week follow-up compared with preintervention ($P < .04$) and postintervention ($P < .04$) for the eyes-open TTB MM-AP and TTB SD-AP. Differences were primarily associated with large ESs, CIs that did not cross zero (Figures 2 and 3), and change scores that exceeded the MDC (Tables 2 and 3). Furthermore, an average of 43.56% (n = 8–9) of the participants responded to the intervention for each outcome measure at a given time comparison (Tables 2 and 3). These findings demonstrated that improvements in ROM, strength, dynamic balance, and self-reported function were achieved and maintained for 2 weeks after the intervention was completed.

DISCUSSION

We hypothesized that a 4-week multimodal rehabilitation program would create statistically significant and clinically relevant improvements in DROM, isometric strength, dynamic and static postural control, and self-reported function. Our findings supported this hypothesis, as we found improvements in DROM, isometric strength, dynamic postural control, self-reported ankle function, overall HRQOL, and fear avoidance during the physical activity measurements after the 4-week multimodal rehabilitation program. For static postural control, only the eyes-open TTB MM-AP and TTB SD-AP were different at the 2-week follow-up session. Improvements in DROM, most isometric strength measures, dynamic postural control, and most self-reported function measures were maintained 2 weeks after the intervention was completed. Improvements were also primarily associated with change scores that surpassed the MDC and large ESs (>0.61), indicating that these changes were clinically meaningful. Cumulatively, our results suggested that a 4-week multimodal rehabilitation program can be used to improve a wide range of disease- and patient-oriented insufficiencies associated with CAI.

Dorsiflexion ROM restrictions are a common impairment associated with CAI.[7] Clinically, enhanced DROM could improve structural adaptations and enhance functional movement patterns.[7] We found improvements in DROM, as measured using the WBLT, immediately after our intervention and at the 2-week follow-up. These improvements were associated with large ESs (postintervention ES = 1.29, 2-week follow-up ES = 1.27) and change scores (postintervention = 1.17 cm, 2-week follow-up = 1.54 cm) that exceeded the calculated MDC (0.54 cm), which may indicate they are clinically meaningful. These findings are comparable with those reported in other CAI investigations,[8,13,14,23] in which researchers used isolated joint mobilizations or a static-stretching intervention (change range = 1.4–2.23 cm; ES range = 0.30–3.00), despite the considerably larger treatment volume in our study. Our findings of sustained DROM improvements after our intervention ceased are also similar to those of previous 1-week[8] and 6-month[13] follow-up investigations. These findings cumulatively indicate that multiple bouts of joint mobilizations and static stretching can produce clinically meaningful improvements in DROM that remain after the treatment program ends.

Improvements were identified for each Y-Balance Test reach distance at both postintervention and the 2-week follow-up compared with preintervention. These findings are comparable with the isolated effects of joint mobilizations[8] and balance training[16] on Star Excursion Balance Test reach distances. Hoch et al[8] theorized that joint mobilizations resulted in greater reach distances due to improved DROM and the subsequent mechanical freedom to complete the assessment. McKeon et al[16] also identified improvements in the posteromedial and posterolateral reach distances on the Star Excursion Balance Test after a balance-training program. McKeon et al[16] suggested that increased reach distances were due to decreased constraints on the neuromotor system. It is possible that our

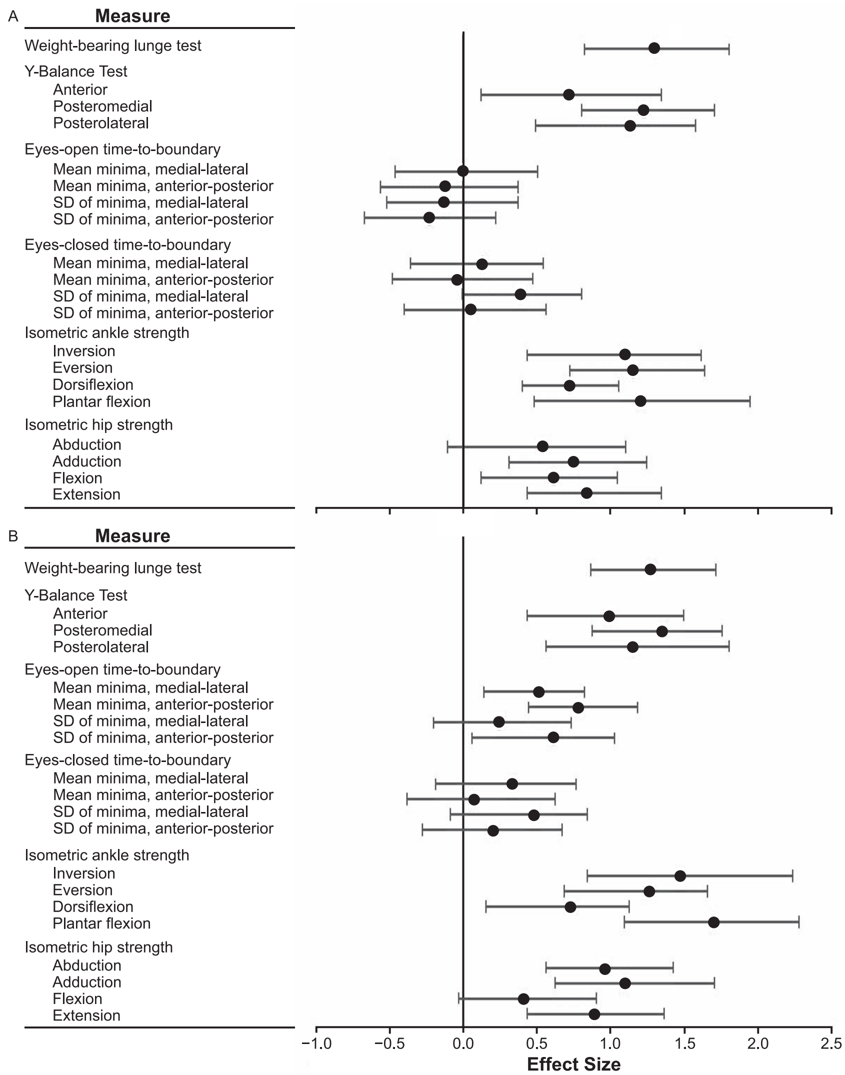

Figure 2. Standardized-response mean effect sizes and 95% confidence intervals for disease-oriented measures. A, Preintervention to postintervention. B, Preintervention to 2-week follow-up.

intervention took advantage of the effects of both interventions. We observed robust increases in anterior reach similar to those in an investigation of isolated joint mobilization.[8] Large improvements in the posteromedial and posterolateral directions were also comparable with the effects of an isolated balance-training program.[16] Overall, our large ESs (>0.72) with CIs that did not cross zero indicated that our multimodal intervention produced meaningful, widespread improvements in dynamic postural control.

Whereas we noted consistent improvements in dynamic postural control, the same did not hold true for static postural-control assessment. We found no preintervention-to-postintervention differences in any TTB variables in either visual condition ($P > .31$). Improvements in the TTB MM-AP and TTB SD-AP during the eyes-open condition were identified at the 2-week follow-up compared with preintervention, which were similar in magnitude to improvements in these TTB variables after a single talocrural joint-mobilization treatment.[14] However, another investigation[36] of the effects of a 2-week talocrural joint-mobilization intervention demonstrated no immediate or 1-week follow-up changes in TTB variables. Furthermore, these differences varied considerably from the findings of McKeon et al,[16] who reported improvements in the TTB variables during the eyes-closed condition immediately after the same balance-training program that we used. Our study revealed improved TTB only at 2 weeks after the intervention was completed. Lastly, comparison with other multimodal protocols[20,21] provided contrasting results, as improvements in static postural control (TTB, center-of-pressure data) have been widely noted immediately after protocol completion. However, our findings and those of Burcal et al[21] suggested that it may take time for certain neuromotor alterations to manifest postintervention, as their TTB improvements were substantially larger at 1-week postintervention, similar to our 2-week improvements. Alternatively, the interaction of treatments may have inhibited initial improvements in postural control. Future research is needed to examine the effects of rehabilitation on static postural control in those with CAI and to incorporate longer follow-ups to evaluate the adaptations of the neuromotor system over time.

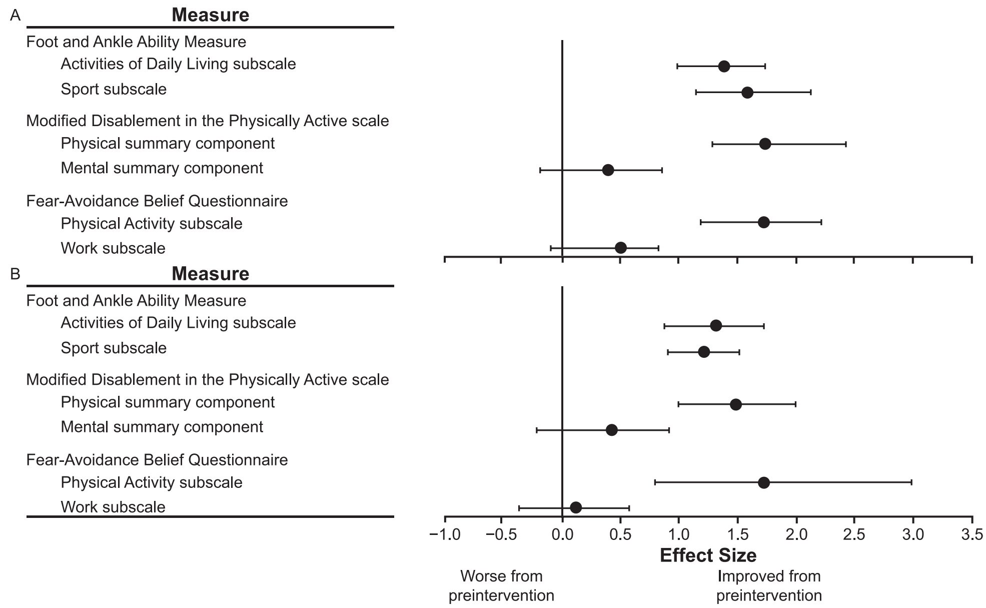

Figure 3. Standardized-response mean effect sizes and 95% confidence intervals for patient-oriented measures. A, Preintervention to postintervention. B, Preintervention to 2-week follow-up.

Improvements in ankle and hip strength compared with preintervention measurements were identified at postintervention and the 2-week follow-up. The identified improvements in ankle strength were associated with large ESs (>0.72) and CIs that did not cross zero. These findings were consistent with previous strength-training investigations,[37] as well as a recent multimodal CAI intervention investigation.[20] The similarities confirm that strength-training programs, as well as combined CAI interventions, can result in large improvements in ankle strength immediately after a 4-week or 6-week protocol. Our results also demonstrated that the ankle-strength gains were still present 2 weeks after the 4-week protocol, indicating that our multimodal intervention may produce lasting benefit. Lastly, to our knowledge, this is one of the first investigations to examine the effect of a multimodal rehabilitation program on hip strength in those with CAI. Whereas our intervention did not target hip strength directly, we found immediate improvements in hip strength after our 4-week intervention. These changes were most likely the result of the functional activities incorporated in the balance-training program. How gains in hip strength contribute to improved deficits associated with CAI should be further evaluated.

In the CAI literature, the assessment of self-reported function after an intervention has primarily focused on the ankle using the FAAM-ADL and the FAAM-Sport questionnaires. Investigators have demonstrated improvements in self-reported ankle function after joint mobilizations,[13,23] balance training,[15,16] and stretching,[23] as well as a combination of these interventions.[19–21] We noted similar changes in the FAAM-ADL (preintervention to postintervention = 7.14%, preintervention to 2-week follow-up = 13.96%) and the FAAM-Sport (preintervention to postintervention = 11.25%, preintervention to 2-week follow-up = 12.5%) scores. Whereas we observed a main effect of time for the FAAM-Sport that was not different, the changes surpassed the calculated MDC (7.99%) and were associated with large ESs (>1.21). Cumulatively, these findings in combination with the previous literature support the implementation of a rehabilitation protocol that combines established interventions to improve ankle-specific self-reported function in those with CAI.

Researchers[4] have demonstrated that individuals with CAI reported decreased overall HRQOL, as well as increased fear avoidance. These factors may be associated with reports[5] of decreased physical activity levels in the population with CAI. We identified improvements in overall HRQOL using the mDPA-PSC and fear avoidance using the FABQ-PA. These improvements were associated with changes that exceeded the MDC (Table 2) and large ESs (Figure 2). However, mDPA-MSC scores were unchanged. This outcome may represent external factors influencing psychological health that were not accounted for in our multimodal rehabilitation program. Cumulatively, our results indicated that the multimodal rehabilitation program was capable of creating multidimensional improvements in HRQOL from the patient's perspective.

To further analyze the data, we examined the rate of responders by determining the number of participants with change scores that exceeded the calculated MDCs for each variable. These analyses are presented in Tables 2 and 3. The most responders were identified for DROM and self-reported function, as both primarily had more than 65% of the participants exceeding the MDC postintervention. Dynamic postural control and strength had moderate response rates, with about 50% of participants demonstrating improvements that exceeded the MDC. Lastly, static balance demonstrated the lowest responder rates, ranging from 5% to 45%. Low response rates for static balance may have indicated that our intervention did not provide enough challenge; however, no participant progressed to the most challenging level of any balance-program tasks. Perhaps supplemental sensory stimulations, such as plantar cutaneous massage, are needed to enhance static postural-

Table 2. Disease-Oriented Outcomes: Means ± SDs, Change Scores, and Minimal Detectable Change Scores

Variable	Time				Change Score		Minimal Detectable Change	Postintervention Responders, n (%)	2-wk Follow-Up Responders, n (%)
	Baseline	Preintervention	Postintervention	2-wk Follow-Up	Preintervention to Postintervention	Preintervention to 2-wk Follow-Up			
Weight-bearing lunge test, cm	8.53 ± 3.38	8.59 ± 3.54	9.75 ± 3.49[a]	10.13 ± 3.49[a]	1.17 ± 0.90	1.54 ± 1.22	0.54	13 (65)	15 (75)
Y-Balance test direction, %									
Anterior	57.99 ± 5.72	58.82 ± 7.29	61.57 ± 5.89[a]	62.19 ± 5.07[a]	2.75 ± 3.81	3.37 ± 3.41	3.11	8 (40)	9 (45)
Posteromedial	98.44 ± 7.40	99.03 ± 6.96	105.97 ± 6.02[a]	106.00 ± 6.42[a]	6.95 ± 5.68	6.98 ± 5.16	4.57	10 (50)	11 (55)
Posterolateral	95.49 ± 6.72	97.78 ± 6.38	104.04 ± 5.37[a]	104.67 ± 5.98[a]	6.25 ± 5.52	6.89 ± 5.98	4.48	9 (45)	11 (55)
Time to boundary, s									
Eyes open									
Mean minima mediolateral	1.88 ± 0.46	1.84 ± 0.47	1.84 ± 0.53	2.07 ± 0.65	−0.00 ± 0.45	0.23 ± 0.45	0.24	3 (15)	6 (30)
Mean minima anteroposterior	5.04 ± 1.59	5.02 ± 1.82	4.88 ± 1.27	5.83 ± 2.06[a,b]	−0.14 ± 1.14	0.81 ± 1.04	0.71	2 (10)	9 (45)
SD of minima mediolateral	1.52 ± 0.43	1.44 ± 0.57	1.35 ± 0.60	1.58 ± 0.61	−0.09 ± 0.74	0.14 ± 0.57	0.52	1 (5)	5 (25)
SD of minima anteroposterior	3.29 ± 1.02	3.22 ± 1.12	3.00 ± 0.91	3.73 ± 1.39[a,b]	−0.22 ± 0.97	0.51 ± 0.84	0.92	3 (15)	7 (35)
Eyes closed									
Mean minima mediolateral	0.79 ± 0.23	0.82 ± 0.22	0.85 ± 0.26	0.89 ± 0.28	0.03 ± 0.22	0.06 ± 0.19	0.14	6 (30)	7 (35)
Mean minima anteroposterior	2.24 ± 0.78	2.44 ± 0.89	2.42 ± 0.77	2.50 ± 0.81	−0.03 ± 0.70	0.06 ± 0.75	0.53	2 (10)	5 (25)
SD of minima mediolateral	0.64 ± 0.25	0.59 ± 0.20	0.70 ± 0.29	0.72 ± 0.31	0.11 ± 0.29	0.13 ± 0.26	0.24	5 (25)	3 (15)
SD of minima anteroposterior	1.44 ± 0.50	1.51 ± 0.59	1.53 ± 0.43	1.61 ± 0.60	0.02 ± 0.49	0.10 ± 0.53	0.35	7 (35)	5 (25)
Isometric strength, N/kg									
Ankle									
Dorsiflexion	3.62 ± 0.66	3.86 ± 0.72	4.24 ± 0.91[a]	4.23 ± 0.75[a]	0.38 ± 0.53	0.37 ± 0.52	0.29	8 (40)	7 (35)
Plantar flexion	4.57 ± 0.85	4.41 ± 1.06	5.37 ± 1.01[a]	5.92 ± 1.13[a]	0.97 ± 0.81	1.51 ± 0.89	0.56	15 (75)	18 (90)
Inversion	3.38 ± 1.01	3.80 ± 1.01	4.57 ± 0.75[a]	4.78 ± 0.83[a]	0.77 ± 0.70	0.98 ± 0.67	0.55	13 (65)	14 (70)
Eversion	3.23 ± 0.76	3.66 ± 0.81	4.47 ± 0.81[a]	4.53 ± 0.82[a]	0.81 ± 0.70	0.86 ± 0.68	0.35	15 (75)	13 (65)
Hip									
Abduction	2.02 ± 0.26	2.02 ± 0.33	2.20 ± 0.31	2.29 ± 0.33[a]	0.19 ± 0.29	0.27 ± 0.29	0.26	8 (40)	9 (45)
Adduction	1.89 ± 0.31	1.85 ± 0.33	2.07 ± 0.39[a]	2.09 ± 0.37[a]	0.22 ± 0.29	0.24 ± 0.22	0.23	9 (45)	11 (55)
Flexion	2.07 ± 0.36	2.09 ± 0.33	2.21 ± 0.38[a]	2.21 ± 0.38	0.12 ± 0.20	0.12 ± 0.28	0.24	5 (25)	7 (35)
Extension	2.62 ± 0.48	2.59 ± 0.38	2.87 ± 0.47[a]	2.88 ± 0.43[a]	0.28 ± 0.34	0.29 ± 0.32	0.26	10 (50)	11 (55)

[a] Different from preintervention ($P < .05$).
[b] Different from postintervention ($P < .05$).

Table 3. Patient-Reported Outcomes: Means ± SDs, Change Scores, and Minimal Detectable Change Scores

Variable	Time				Change Score		Minimal Detectable Change	Postintervention Responders, n (%)	2-wk Follow-Up Responders, n (%)
	Baseline	Preintervention	Postintervention	2-wk Follow-Up	Preintervention to Postintervention	Preintervention to 2-wk Follow-Up			
Foot and Ankle Ability Measure									
Activities of daily living subscale, %	87.68 ± 8.47	88.63 ± 8.07	95.77 ± 4.69[a]	97.20 ± 2.95[a]	7.14 ± 5.17	8.57 ± 6.54	5.22	10 (50)	13 (65)
Sport subscale, %	74.06 ± 11.74	80.16 ± 10.2	91.41 ± 7.65	92.66 ± 7.04	11.25 ± 7.13	12.50 ± 10.29	7.99	14 (70)	14 (70)
Modified Disablement in the Physically Active Scale score									
Physical summary component	11.85 ± 7.24	13.25 ± 7.75	6.05 ± 6.90[a]	4.75 ± 5.89[a]	−7.20 ± 4.16	−8.50 ± 5.73	8.05	8 (40)	11 (55)
Mental summary component	2.75 ± 2.86	2.30 ± 2.62	1.30 ± 3.05	1.25 ± 3.04	−1.00 ± 2.60	−1.05 ± 2.48	2.74	5 (25)	5 (25)
Fear-Avoidance Beliefs Questionnaire score									
Physical activity subscale	13.50 ± 3.52	12.60 ± 4.22	6.50 ± 5.01[a]	5.65 ± 4.74[a]	−6.10 ± 3.55	−6.95 ± 4.03	3.89	15 (75)	17 (85)
Work subscale	8.75 ± 7.21	5.20 ± 6.81	2.40 ± 3.02	4.35 ± 5.90	−2.80 ± 5.57	−0.85 ± 7.82	6.69	4 (20)	2 (10)

[a] Different from preintervention ($P < .05$).

control improvements, as suggested by Burcal et al.[21] However, they used the same balance-training program we did and found that it alone did not result in group improvements that exceeded the MDC for TTB, indicating a low number of responders were most likely present as well. Furthermore, previous investigations[21,38–40] of responders in the CAI literature have been limited to 4 studies. Authors of 2 investigations[21,38] evaluated responders using minimally clinically important difference scores for the Foot and Ankle Ability Measure and demonstrated response rates of 33% to 60% as compared with our rates of 50% to 70%. Wikstrom and McKeon[39] demonstrated 25% to 35% responder rates compared with our 5% to 45% responder rates related to static single-limb balance. The differences in responder rates may be due to the type of balance measures used; Wikstrom and McKeon[39] used a clinical, single-limb balance measure, whereas we used a laboratory measure of single-limb balance. Finally, previously reported responder rates for the isolated application of joint mobilizations or stretching programs to improve DROM were similar to those in our study, with scores ranging from 70% to 80%[40] compared with our 65% to 75% rate. The similarity in responder rates may be due to the similarity of our joint-mobilization and stretching programs. With the limited precedent for responder rates, it is difficult to determine if these rates are acceptable for clinical practice. Further investigation of individual-level improvements is needed to enhance our understanding of CAI interventions.

Limitations of our study were the lack of a control group, lack of blinding, and relatively short follow-up period. By not including a control group, we were unable to compare the effects of the 4-week intervention with the natural progression of CAI. Introducing a control or sham group would add rigor to the study design and help confirm the effects of the intervention. A control or sham group would also offer a greater opportunity for blinding. Enhanced blinding could reduce the potential bias in the study due to treatment expectations. Given this limitation, we examined the changes postintervention using traditional statistics along with other metrics of treatment effects: ES, CI, and MDC. Our investigation included a 2-week follow-up period. Whereas this follow-up period enabled us to confirm that many of the improvements due to the intervention persisted beyond the intervention, it did not confirm exactly how long the effects lasted. However, authors of a recent study[13] identified treatment effects that lasted for up to 6 months. Researchers should investigate the duration of treatment effects and explore if maintenance exercises are needed to prolong these effects. Lastly, we did not use an intervention that was based on patient-specific deficits. All participants received every aspect of the intervention, regardless of their baseline status. Perhaps the treatment effects and clinician burden could be improved if interventions were targeted to individually identified deficits as proposed in a new treatment paradigm for CAI.[20] Yet in recent investigations, researchers[38–40] examining predictors of manual therapy treatment success in those with CAI demonstrated that this impairment model might be limiting, as the success of joint-mobilization treatment was related not only to baseline DROM but also to single-limb balance and self-reported function. More research regarding treatment interactions, overall treatment effects, and predicting treatment responders will help enhance CAI rehabilitation models in the future.

CONCLUSIONS

After a 4-week multimodal rehabilitation program that incorporated ankle stretching and strengthening, balance training, and joint mobilizations, individuals with CAI demonstrated improvements in DROM, ankle strength, hip strength, dynamic postural control, ankle-specific function, global wellbeing, and fear-avoidance beliefs. Improvements were identified immediately postintervention and were maintained at 2 weeks after completion. Improvements in static postural control were identified only at the 2-week follow-up and in the eyes-open condition. Large ESs and improvements that exceeded the MDC for our measures indicated that these changes were not only statistically significant but may also be clinically meaningful. This evidence supports the incorporation of a multifaceted evidence-based intervention to enhance a multidimensional profile of health in treating patients with CAI.

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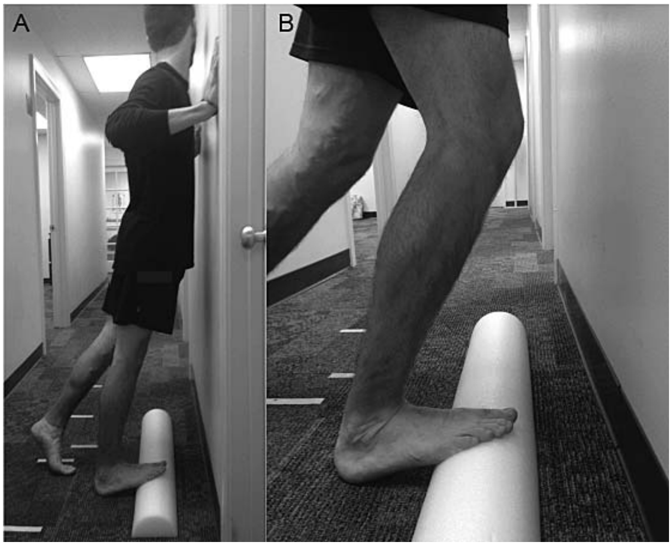
Appendix. Home and Supervised Interventions

Intervention	Description	Illustration
Home[a]		
Gastrocnemius-soleus complex stretching	Completed stretches by placing a half foam roller under the ball of the foot and leaning toward a wall to create ankle dorsiflexion. Stretches were accomplished with the knee in a straight and a slightly bent position. Three sets of 30-s stretches were completed throughout the intervention.	Appendix Figure 1
TheraBand[b] ankle strengthening	Strengthening was conducted in the dorsiflexion, plantar flexion, inversion, and eversion directions. Sets, repetitions, and band strength were progressed as follows during the intervention: Week 1: 3 sets of 10 repetitions with blue band Week 2: 4 sets of 10 repetitions with blue band Week 3: 3 sets of 10 repetitions with black band Week 4: 4 sets of 10 repetitions with black band	
Supervised[c]		
Joint mobilization	Four 2-min sets of Maitland grade III anterior-to-posterior talocrural joint mobilizations with 1-min rest between sets throughout the sessions. Each oscillation was applied from midrange to end range of accessory motion over 1 s.	Appendix Figure 2
Proprioceptive neuromuscular facilitation ankle strengthening	Slow-reversal proprioceptive neuromuscular facilitation technique local to the ankle joint, which consisted of both D1 and D2 ankle patterns. The investigator applied manual resistance over the course of 3–5 s per repetition. Sets and repetitions were progressed as follows during the intervention: Sessions 1–3: 3 sets of 10 repetitions Sessions 4–6: 3 sets of 15 repetitions Sessions 7–9: 4 sets of 10 repetitions Sessions 10–12: 4 sets of 15 repetitions	
Balance training	Balance training was conducted based on the protocol established by McKeon et al[16] and followed their established recommendations for progression.	More details and schematics of the balance training program were presented in the Appendix of the study by McKeon et al.[16]

[a] Daily completion over the 4-wk intervention.
[b] Hygenic Corporation, Akron, OH.
[c] Twelve sessions over the 4-wk intervention.



Appendix Figure 1. Gastrocnemius-soleus complex stretching exercise completed at home.

Appendix Figure 2. Supervised joint mobilization.