2012

Two-week Joint Mobilization Intervention Improves Self-Reported Function, Range of Motion, and Dynamic Balance in Those With Chronic Ankle Instability

Matthew C. Hoch
Old Dominion University, mhoch@odu.edu

Richard D. Andreatta

David R. Mullineaux

Robert A. English

Jennifer M. Medina McKeon

See next page for additional authors

Original Publication Citation

Hoch, M. C., Andreatta, R. D., Mullineaux, D. R., English, R. A., McKeon, J. M. M., Mattacola, C. G., & McKeon, P. O. (2012). Two-week joint mobilization intervention improves self-reported function, range of motion, and dynamic balance in those with chronic ankle instability. *Journal of Orthopaedic Research, 30*(11), 1798-1804. doi:10.1002/jor.22150

Authors
Matthew C. Hoch, Richard D. Andreatta, David R. Mullineaux, Robert A. English, Jennifer M. Medina McKeon, Carl G. Mattacola, and Patrick O. McKeon

Two-Week Joint Mobilization Intervention Improves Self-Reported Function, Range of Motion, and Dynamic Balance in Those With Chronic Ankle Instability

Matthew C. Hoch,[1] Richard D. Andreatta,[2] David R. Mullineaux,[3] Robert A. English,[4] Jennifer M. Medina McKeon,[5] Carl G. Mattacola,[5] Patrick O. McKeon[5]

[1]Department of Human Movement Sciences, College of Education, Old Dominion University, 1005 Student Recreation Center, Norfolk, Virginia 23529, [2]Division of Communication Sciences & Disorders, College of Health Sciences, University of Kentucky, Lexington, Kentucky, [3]Faculty of Health & Life Sciences, School of Sport, Coaching, & Exercise Science, University of Lincoln, Lincoln, United Kingdom, [4]Division of Physical Therapy, College of Health Sciences, University of Kentucky, Lexington, Kentucky, [5]Division of Athletic Training, College of Health Sciences, University of Kentucky, Lexington, Kentucky

Received 30 January 2012; accepted 30 April 2012
Published online 18 May 2012 in Wiley Online Library (wileyonlinelibrary.com). DOI 10.1002/jor.22150

ABSTRACT: We examined the effect of a 2-week anterior-to-posterior ankle joint mobilization intervention on weight-bearing dorsiflexion range of motion (ROM), dynamic balance, and self-reported function in subjects with chronic ankle instability (CAI). In this prospective cohort study, subjects received six Maitland Grade III anterior-to-posterior joint mobilization treatments over 2 weeks. Weight-bearing dorsiflexion ROM, the anterior, posteromedial, and posterolateral reach directions of the Star Excursion Balance Test (SEBT), and self-reported function on the Foot and Ankle Ability Measure (FAAM) were assessed 1 week before the intervention (baseline), prior to the first treatment (pre-intervention), 24–48 h following the final treatment (post-intervention), and 1 week later (1-week follow-up) in 12 adults (6 males and 6 females) with CAI. The results indicate that dorsiflexion ROM, reach distance in all directions of the SEBT, and the FAAM improved ($p < 0.05$ for all) in all measures following the intervention compared to those prior to the intervention. No differences were observed in any assessments between the baseline and pre-intervention measures or between the post-intervention and 1-week follow-up measures ($p > 0.05$). These results indicate that the joint mobilization intervention that targeted posterior talar glide was able to improve measures of function in adults with CAI for at least 1 week. J Orthop Res 30:1798–1804, 2012

Keywords: ankle sprain; dorsiflexion; balance; manual therapy; self-reported function

Lateral ankle sprains continue to be the most common injury sustained by physically active individuals and create an annual healthcare burden of over $4 billion in the U.S. alone.[1,2] Although these injuries are often considered innocuous, up to 70% of individuals who sustain a single lateral ankle sprain experience residual symptoms, recurrent bouts of instability, additional ankle sprains, and reduced functional capacity.[3–5] These negative sequelae associated with acute ankle sprains are the primary characteristics of chronic ankle instability (CAI).[6] The prevalence of CAI combined with the associated decreased quality of life[3] and risk of developing co-morbidities such as post-traumatic ankle osteoarthritis[7,8] advocates for further development of interventions to address this clinical phenomenon.

CAI has been linked to several mechanical and functional insufficiencies; however, their relationship as it relates to the manifestation of this condition is unclear.[6,9] Several mechanical impairments have been identified as contributing factors for CAI.[6] The primary mechanical impairments include increased anterior joint laxity,[10] reduced posterior talar glide,[11] and reduced dorsiflexion range of motion (ROM).[12,13] Dorsiflexion ROM deficits may be related to a disruption in normal talar arthrokinematics as a result of restrictions in noncontractile tissues and degenerative changes in ankle complex structure.[6] This is supported by studies that identified either restrictions in posterior talar glide[11,14] or the presence of an anterior positional fault of the talus in relation to the ankle mortise.[15,16] A loss of dorsiflexion ROM that is arthrogenic in nature may also contribute to the functional impairments associated with CAI by disrupting the normal transmission of afferent information available to the sensorimotor system.[6,17] Deficits in postural control and other functional impairments are thought to be the result of a loss in somatosensory information from damaged ligamentous mechanoreceptors; however, alterations in sensory input may also be associated with changes in arthrokinematic function.[16–18] While other factors such as central adaptations in motor organization may contribute to sensorimotor alterations,[19] the potential synergistic relationship between local mechanical and functional alterations associated with CAI warrants further investigation.

While the connection between specific impairments and the clinical manifestation of CAI is unclear, interventions that address multiple aspects of impairment are essential for alleviating activity limitations and participation restrictions in people with CAI.[9] To address mechanical impairments, previous investigators[14,17,17,20,21] utilized joint mobilization manual therapy techniques to address deficits in posterior talar glide and dorsiflexion ROM. Joint mobilization was used to increase ROM and arthrokinematic

Grant sponsor: University of Kentucky's College of Health Sciences Office of Research.
Correspondence to: Matthew C. Hoch (T: 757-683-4351; F: 757-683-4270; E-mail: mhoch@odu.edu)

motion by increasing the extensibility of noncontractile tissues.[22] A single ankle joint mobilization treatment provided resolution of mechanical impairments associated with a history of lateral ankle sprain.[14,17,20,21] Also, a single joint mobilization treatment was associated with improvements in single limb static postural control[17] and facilitation of soleus motoneuron pool excitability.[23] Despite these findings, a single joint mobilization treatment was unable to influence dynamic balance indicating that the acute mechanical and neuromuscular alterations may not create immediate changes in functional activities.[17] Therefore, it appears joint mobilization can target both mechanical and functional impairments; however, additional research is needed to determine the extent of these effects.

The major limitation of the research evidence associated with joint mobilization and CAI is the lack of studies examining multiple joint mobilization treatments. Examining the effect of multiple treatments would enhance clinical application and allow assessment of patient-oriented measures of function to compliment measures of mechanical and functional impairment. Therefore, we examined the effect of a 2-week anterior-to-posterior ankle joint mobilization intervention on weight-bearing dorsiflexion ROM, dynamic postural control, and self-reported function in those with CAI.

METHODS

Design

We employed a prospective cohort design as part of a larger study examining the effect of joint mobilization on functional outcomes for subjects with CAI. The independent variable was time (baseline, pre-intervention, post-intervention, 1-week follow-up). The dependent variables were dorsiflexion ROM, normalized reach distances on the Star Excursion Balance Test (SEBT), and self-reported function. Subjects reported to the research laboratory for four separate data collection sessions and underwent six joint mobilization treatments across 4 weeks.

Subjects

Twelve subjects with CAI (6 M, 6 F; age $= 27.4 \pm 4.3$ years; height $= 175.4 \pm 9.78$ cm; mass $= 78.4 \pm 11.0$ kg) volunteered to participate in the study. Subjects were recruited using advertisements posted throughout a large university over a 4-month period. An ankle sprain was defined as an incident in which the rearfoot was inverted or supinated and resulted in a combination of swelling, pain, and time lost or modification of normal function for $\geq$1 day.[6] To be included, subjects had to report a history of $\geq$1 ankle sprain and $\geq$2 episodes of "giving way" within the past 3 months. This was quantified by answering "yes" to question 1 and for a total of at least four questions on the Ankle Instability Instrument.[24] An episode of giving way was described as an incident in which the rearfoot suddenly rolled, felt weak, or lost stability; however, the individual did not sustain an ankle sprain and was able to continue with normal function.[6] Subjects also had to report functional loss by reporting disability scores of $\leq$90% on the Foot and Ankle Ability Measure (FAAM) Activities of Daily Living (ADL) Scale and a score of $\leq$80% on the FAAM-Sport Scale.[25] The FAAM is designed to quantify activity limitations and participation restrictions in the previous week associated with health conditions affecting the foot and ankle.[25] The ADL portion of FAAM contains 21 activity related items, while the FAAM-Sport subscale contains eight sport-related items.[25] In the event subjects reported a bilateral history of ankle sprains, the limb with the greatest reported functional loss on the FAAM was included. The subjects reported an average of 5.3 ± 5.5 ankle sprains. The average number of episodes of giving way was 8.4 ± 7.4. Exclusion criteria consisted of the subject reporting an acute ankle sprain within the past 6 weeks, a previous history of lower extremity surgeries or fracture, other lower extremity injuries within the past 6 months that resulted in time lost or modification of normal function for $\geq$1 day, and other health conditions known to affect balance. Prior to participation, all subjects provided written informed consent in compliance with the institutional review board. No dropouts were experienced at any point in the study.

Testing Procedures

After being enrolled, subjects participated in the 1st data collection session (baseline). Subjects were then instructed to maintain normal physical activity and ADLs and report back in 1 week for the 2nd data collection session (pre-intervention). Immediately thereafter, subjects received their 1st joint mobilization treatment and returned to the laboratory for five additional treatments over the following 2 weeks. The 3rd collection session (post-intervention) was conducted within 24–48 h following the final treatment. After another week, 1-week follow-up data were collected (Fig. 1). During each collection session, dependent measures including dorsiflexion ROM, dynamic postural control, and self-reported function were collected in a counterbalanced order that was

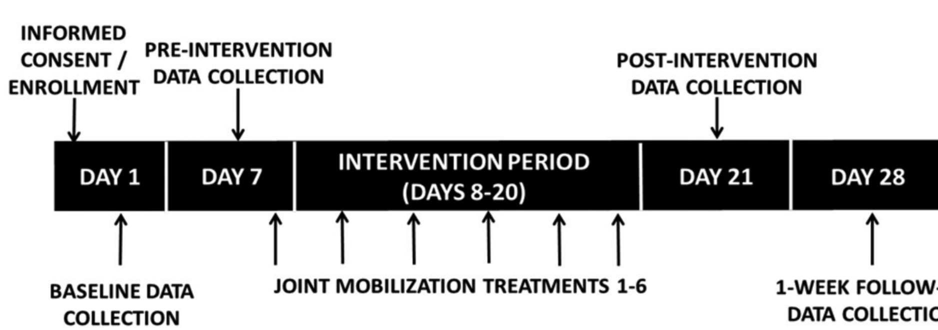

Figure 1. Study timeline representing the four data collection sessions (baseline, pre-intervention, post-intervention, 1-week follow-up) and the six joint mobilization treatment sessions over a 28-day period.

maintained across collections for each subject. All dependent measures were collected barefoot using previously described protocols.[17]

Dorsiflexion ROM

The weight-bearing lunge test was performed using the knee-to-wall principle.[17] Subjects performed three practice and three analysis trials of the test on the involved limb.[17] The uninvolved limb was positioned alongside and behind the involved limb and was used to maintain stability. When subjects could maintain heel and knee contact, they were progressed away from the wall and repeated the modified lunge. All subjects started the test ~2 cm from the wall and initially progressed in 1 cm increments until the first lunge that the heel lifted from the floor or the knee failed to make contact with the wall. Following the first failed attempt, foot placement of the involved limb was adjusted in smaller increments to achieve the maximum distance from the wall. Maximum dorsiflexion was the distance of the great toe from the wall based on the furthest distance the foot could be placed without the heel lifting off the ground while the knee was able to touch the wall. After achieving maximum dorsiflexion ROM, subjects stood, resumed a comfortable position, and performed the next trial from the original starting position. The average of the three analysis trials was calculated and used for statistical analysis. There is ~3.6° of dorsiflexion ROM for every 1 cm in distance away from the wall.[26]

Dynamic Postural Control

Dynamic balance was assessed through the anterior, posteromedial, and posterolateral directions of the SEBT based on the recommendations of Hertel.[9] Subjects were positioned according to a series of tape measures secured to the floor. Equal halves of the length and width of the involved foot were in each quadrant of the SEBT. This system for foot positioning ensured accurate repositioning over the four testing sessions. Subjects were instructed to perform maximal reaches with the uninvolved limb followed by a single, light toe touch on the tape measure. During the trial, if the hands did not remain on the hips, the position of the stance foot was not maintained, the heel did not remain in contact with the floor, or the subject lost balance, the trial was discarded and repeated. Each subject performed four practice trials in each direction on the involved limb and three trials in each direction for analysis.[27] Distances were measured in centimeters, normalized to each subject's leg length, and multiplied by 100.[28] Leg length was measured as the distance from the anterior superior iliac spine to the distal tip of the medial malleolus.[28] Longer normalized reach distances were indicative of better dynamic balance. The average of the three trials for each reach direction was calculated and used for statistical analysis with each reach direction independently examined.

Joint Mobilization Intervention

The intervention consisted of six visits to the laboratory. During each session, each subject received 2, 2-min sets of Maitland Grade II talocrural joint traction and 4, 2-min sets of Maitland Grade III talocrural joint mobilization with 1 min of rest between sets. Therefore, the treatment volume was 12 min (4 min of traction and 8 min of joint mobilization) during each session. Traction was employed prior to the posterior glide joint mobilizations to distract the talus from the ankle mortise to promote posterior gliding of the talus. During traction, the clinician applied intermittent force to the point of feeling an increase in the talocrural joint space without moving into tissue restriction. The joint mobilization technique consisted of stabilizing the distal tibia and fibula and mobilizing the talus in an anterior-to-posterior direction in accordance with a previously established protocol.[17] The joint mobilization was operationally defined as large-amplitude, 1-s rhythmic oscillations from the joint's mid-range to end range with translation taken to tissue resistance.[29,30] Compliance was 100%; all subjects received all treatments within the designated period. For each session, 208 ± 13 oscillations were performed and subjects received 1,251 ± 40 oscillations over the six treatment periods. A grade III joint mobilization was selected in an attempt to increase the posterior capsular endpoint and provide stimulation of articular mechanoreceptors from oscillations that span the length of the available accessory motion. All treatments were conducted by the same Certified Athletic Trainer with 5 years of experience.

Minimal Detectable Change Scores

Because no control group was used, minimal detectable change (MDC) scores were calculated to determine the minimal change required within our dependent variables to achieve changes beyond the error of the measurements. MDC scores were determined using intersession reliability [intraclass correlation coefficient (2,1) and the standard error of measurement (SEM)] from the data collected during the baseline and pre-intervention sessions. MDC scores were calculated using the formula: $SEM \times \sqrt{2}$.[31,32] Each MDC score is provided next to the respective dependent variable in Table 1.

Table 1. Mean ± SD and Minimal Detectable Change (MDC) for the Foot and Ankle Ability Measure Activities of Daily Living (FAAM-ADL), the FAAM-Sport, Dorsiflexion ROM, and the Anterior, Posteromedial, and Posterolateral Directions of the Star Excursion Balance Test (SEBT) across the Four Testing Sessions ($n = 12$).

Dependent Variable	Baseline	Pre-Intervention	Post-Intervention	1-Week Follow-up	MDC
FAAM-ADL (%)	77.99 ± 13.11	78.27 ± 12.62	87.30 ± 11.07[a,b]	86.80 ± 11.06[a,b]	3.96
FAAM-Sport (%)	56.25 ± 14.72	58.59 ± 11.08	73.69 ± 17.65[a,b]	74.21 ± 18.94[a,b]	7.90
Dorsiflexion ROM (cm)	10.87 ± 3.71	10.83 ± 3.86	12.18 ± 3.65[a,b]	12.29 ± 3.58[a,b]	0.26
Anterior SEBT (%)	75.06 ± 5.19	76.18 ± 5.76	78.30 ± 5.63[a,b]	78.71 ± 4.97[a,b]	1.56
Posteromedial SEBT (%)	93.30 ± 10.37	91.86 ± 10.33	96.23 ± 10.95[a,b]	97.47 ± 11.20[a,b]	3.36
Posterolateral SEBT (%)	85.92 ± 11.97	87.15 ± 12.60	91.92 ± 11.15[a,b]	93.09 ± 12.96[a,b]	4.28

[a]Significant increase compared to baseline ($p \leq 0.05$). [b]Significant increase compared to pre-intervention ($p \leq 0.05$).

Statistical Analysis

Separate one-way ANOVAs were used to examine differences in the FAAM-ADL, the FAAM-Sport, dorsiflexion ROM, and each direction of normalized reach distance on the SEBT. The independent variable was time (baseline, pre-intervention, post-intervention, 1-week follow-up). Post hoc comparisons were completed using Fisher's LSD in the presence of a time effect. The significance level for all analyses was set at $p \leq 0.05$. No correction for multiple comparison was performed on the alpha level to protect against making a type II error.[33] Instead, effect sizes (ES) were calculated based on the mean difference, the standard deviation (SD) of the differences, and the correlation of repeated-measures using a bias-corrected *Hedge's g* with corresponding 95% confidence intervals (CI).[34] ES were interpreted as weak (0–0.39), moderate (0.40–0.69), and strong ($\geq$0.70).[35] Statistical analyses were conducted using PASW version 18.0 (Chicago, IL) and Excel 2007 (Microsoft, Redmond, WA).

RESULTS

Means ($\pm$ SD) and the MDC for the FAAM-ADL, FAAM-Sport, dorsiflexion ROM, and SEBT measures are presented in Table 1. A significant time effect was found for the FAAM-ADL ($p = 0.001$), FAAM-Sport ($p = 0.001$), dorsiflexion ROM ($p < 0.001$), and the anterior ($p < 0.001$), posteromedial ($p = 0.003$), and posterolateral ($p < 0.001$) directions of the SEBT. Post hoc analyses determined that post-intervention and 1-week follow-up measures were significantly improved ($p \leq 0.01$ for all) when compared to baseline and pre-intervention measures. Also, no differences were identified between baseline and pre-intervention or post-intervention and 1-week follow-up measures for any dependent variables ($p > 0.05$). The ES $\pm$ 95% CI for all post hoc comparisons are presented in Figure 2.

DISCUSSION

Our main finding was that a 2-week joint mobilization intervention altered mechanical and functional impairments by significantly improving self-reported function, dorsiflexion ROM, and dynamic postural control in those with CAI. These improvements lasted for at least 1 week and signify that the intervention effectively improved patient-oriented and clinician-oriented measures of function[36] in this cohort of individuals with CAI. Overall, our results suggest that joint mobilization should be considered during the treatment regimen in patients with CAI.

Those with CAI have perceived reductions in levels of activity and participation measured through patient-oriented measures of function.[3] The average improvements in function 1 week following the intervention were ~8% and 15% for the FAAM-ADL and FAAM-Sport, respectively. This indicates that self-reported function improved beyond the previously established minimally clinically important difference[25] and the MDC scores calculated in this study. Improvements in self-reported function were supported by moderate-to-large ES (0.43 ± 0.81–0.80 ± 0.83) between the measures collected prior to and following intervention. These results show that the improvements in self-reported function were beyond the instrument error and represent meaningful improvements in patient-reported function. Therefore, clinicians may be able to use joint mobilization to enhance quality of life in patients with CAI.

A common clinical consideration in the treatment of ankle sprains and ankle instability is dorsiflexion ROM. A previous study[17] demonstrated that a single bout of joint mobilization produced a significant though modest increase in dorsiflexion ROM. The joint mobilization intervention in this investigation also significantly improved dorsiflexion ROM indicating the Maitland Grade III anterior-to-posterior talar glide joint mobilization most likely had an impact on the extensibility and flexibility of noncontractile tissues local to the talocrural joint. The increase in lunge distance on the weight-bearing lunge test was 1.4 cm following the intervention, which equated to a ~5° increase in ROM[26] and is 3.5× greater than the previously reported[17] increase following a single treatment. Therefore, multiple bouts of joint mobilization have mechanical benefits that may provide a resolution to the dorsiflexion ROM deficits commonly associated with CAI in clinical practice.

Following the intervention, significant increases in reach distance were identified in the anterior, posteromedial, and posterolateral directions of the SEBT. Because improvements were identified in ROM, the increased reach distances can likely be attributed to the ability to incorporate additional motion into the movement strategies on this assessment. This is a positive progression upon the previous study,[17] which determined a single joint mobilization treatment was unable to change SEBT reach distances in the presence of modest increases in dorsiflexion ROM. The more robust increase in dorsiflexion ROM, the longer intervention period, and the longer time from the application of joint mobilization to re-assessment may have allowed the freed mechanical degrees of freedom to be integrated into functional strategies on the SEBT. Exploring how mechanical degrees of freedom are incorporated into movement strategies following joint mobilization should be systematically investigated in future research.

We hypothesized that the joint mobilization intervention would have the greatest impact on the anterior reach direction of the SEBT based on evidence from previous studies.[37,38] Anterior reach deficits have been thought to be most strongly related to impairments in dorsiflexion ROM. Our results indicate that the joint mobilization intervention improved the anterior, posteromedial, and posterolateral directions at nearly equal magnitudes. While the observed increases in dorsiflexion ROM provides a logical explanation for increases in anterior reach,[39] significant improvements were also identified in the posteromedial and posterolateral directions. Because no other ROMs were

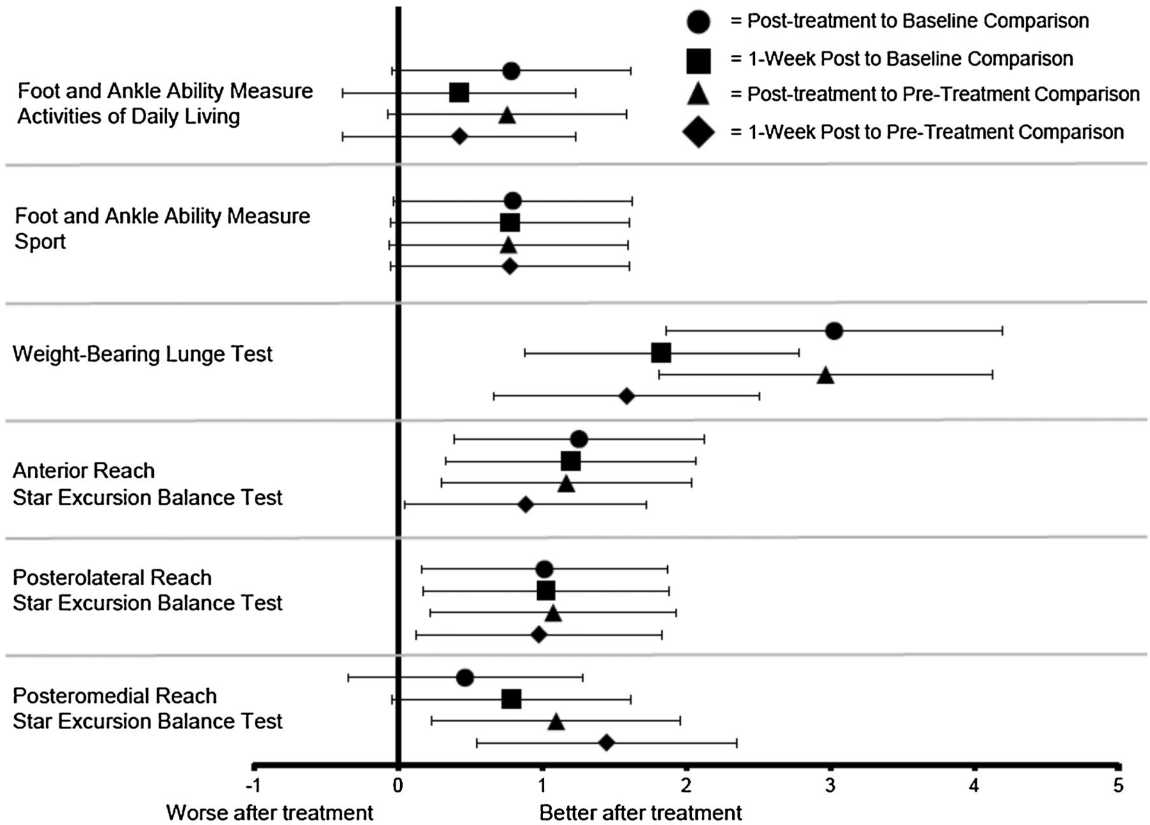

Figure 2. Effect sizes and 95% confidence intervals for the Foot and Ankle Ability Measure Activities of Daily Living, the Foot and Ankle Ability Measure Sport, Weight-Bearing Lunge Test, and the anterior, posteromedial, and posterolateral directions of the Star Excursion Balance Test for all significant post hoc comparisons. Positive effect sizes represent improvements following the joint mobilization intervention.

investigated, we can only speculate that weight-bearing knee and hip flexion may have also increased based on the known coupling between weight-bearing dorsiflexion and these motions.[11] Previous investigators[40] determined that knee and hip flexion ROM significantly influence posteromedial and posterolateral reach distances. This implies that the joint mobilization intervention resulted in increased weight-bearing dorsiflexion and may have concurrently enabled greater amounts of knee and hip flexion to be incorporated into anterior and posterior reach distances.

The joint mobilization intervention was intended to simulate a volume and frequency consistent with a clinical treatment regimen. While the traction and joint mobilization techniques were consistent with previously described methods,[22] the intervention volume and frequency exceeded other studies that used oscillatory joint mobilization techniques.[17,29,41] The treatment time across the six treatments was 48 min of oscillations. Previous studies[17,24] employed as little as 30 sec, while Green et al.[41] administered 8 min of oscillations. The more robust increases in dorsiflexion ROM and improvements in SEBT performance observed in our study may be attributed to the much greater volume and frequency of treatment. Additionally, we employed 4 min of joint traction prior to posterior talar glides. Traction was implemented because it is commonly applied prior to administering gliding joint mobilizations clinically.[22] While traction may have contributed to the findings of this study, this technique was employed only to enhance the configuration of the boney surfaces to maximize the gliding joint mobilizations.

The major limitations of this design are the short follow-up period, the lack of blinding, and the lack of a control or sham group. Based on our results, there appear to be distinct benefits of utilizing joint mobilizations in those with CAI. However, the average increases in the FAAM-ADL and FAAM-Sport scores following intervention indicated that these individuals would still be classified with CAI based on the a priori level of functional deficits required to be included in the study. Therefore, joint mobilizations should be investigated in combination with other rehabilitation strategies that attempt to improve self-reported function and sensorimotor control through well-designed randomized controlled trials with a longitudinal follow-up. Interventions including dynamic balance training[37] and comprehensive rehabilitation programs[42] have also improved self-reported function and sensorimotor control in individuals with CAI. Combining those interventions with the joint mobilization intervention examined in our study may provide a synergistic coupling which may result in greater functional outcomes for those with CAI.

In conclusion, a 2-week joint mobilization intervention that targeted the extensibility of the posterior ankle noncontractile structures resulted in significant improvements in self-reported function, dorsiflexion ROM, and increased reach distance in the anterior, posteromedial, and posterolateral directions of the SEBT in those with CAI. By targeting local mechanical impairments in ankle function, the intervention improved patient-oriented and clinician-oriented functional measures. Cumulatively, our findings support incorporating posterior talar glide joint mobilizations into the treatment regimen for individuals with CAI.

ACKNOWLEDGMENTS

All data were collected at the University of Kentucky. No conflicts of interest were associated with the authors and the results of this research.

REFERENCES

1. Curtis CK, Laudner KG, McLoda TA, et al. 2008. The role of shoe design in ankle sprain rates among collegiate basketball players. J Athl Train 43:230–233.
2. Waterman BR, Owens BD, Davey S, et al. 2010. The epidemiology of ankle sprains in the United States. J Bone Joint Surg Am 92:2279–2284.
3. Wikstrom EA, Tillman MD, Chmielewski TL, et al. 2009. Self-assessed disability and functional performance in individuals with and without ankle instability: a case control study. J Orthop Sport Phys Ther 39:458–467.
4. Anandacoomarasamy A, Barnsley L. 2005. Long term outcomes of inversion ankle injuries. Br J Sport Med 39:e14.
5. Yeung MS, Chan KM, So CH, et al. 1994. An epidemiological survey on ankle sprain. Br J Sports Med 28:112–116.
6. Hertel J. 2002. Functional anatomy, pathomechanics, and pathophysiology of lateral ankle instability. J Athl Train 37:364–375.
7. Valderrabano V, Hintermann B, Horisberger M, et al. 2006. Ligamentous posttraumatic ankle osteoarthritis. Am J Sports Med 34:612–620.
8. Gross P, Marti B. 1999. Risk of degenerative ankle joint disease in volleyball players: study of former elite athletes. Int J Sport Med 20:58–63.
9. Hertel J. 2008. Sensorimotor deficits with ankle sprains and chronic ankle instability. Clin Sports Med 27:353–370.
10. Hubbard TJ, Kaminski TW, vander Griend RA, et al. 2004. Quantitative assessment of mechanical laxity in the functionally unstable ankle. Med Sci Sport Exer 36:760–766.
11. Denegar CR, Hertel J, Fonseca J. 2002. The effect of lateral ankle sprain on dorsiflexion range of motion, posterior talar glide, and joint laxity. J Orthop Sport Phys Ther 32:166–173.
12. Drewes LK, McKeon PO, Kerrigan DC, et al. 2009. Dorsiflexion deficit during jogging with chronic ankle instability. J Sci Med Sport 12:685–687.
13. Youdas JW, McLean TJ, Krause DA, et al. 2009. Changes in active ankle dorsiflexion range of motion after acute inversion ankle sprain. J Sport Rehabil 18:358–374.
14. Vicenzino B, Branjerdporn M, Teys P, et al. 2006. Initial changes in posterior talar glide and dorsiflexion of the ankle after mobilization with movement in individuals with recurrent ankle sprain. J Orthop Sport Phys Ther 36:464–471.
15. Hubbard TJ, Hertel J. 2006. Mechanical contributions to chronic lateral ankle instability. Sports Med 36:263–277.
16. Wikstrom EA, Hubbard TJ. 2010. Talar positional fault in persons with chronic ankle instability. Arch Phys Med Rehabil 91:1267–1271.
17. Hoch MC, McKeon PO. 2011. Joint mobilization improves spatiotemporal postural control and range of motion in those with chronic ankle instability. J Orthop Res 29:326–332.
18. McKeon PO, Booi MJ, Branam B, et al. 2010. Lateral ankle ligament anesthesia signficantly alters single limb postural control. Gait Posture 32:374–377.
19. Hass CJ, Bishop MD, Doidge D, et al. 2010. Chronic ankle instability alters central organization of movement. Am J Sports Med 38:829–834.
20. van der Wees PJ, Lenssen AF, Hendriks EJ, et al. 2006. Effectiveness of exercise therapy and manual mobilisation in ankle sprain and functional instability: a systematic review. Aust J Physiother 52:27–37.
21. Reid A, Birmingham TB, Alcock G. 2007. Efficacy of mobilization with movement for patients with limited dorsiflexion after ankle sprain: a crossover trial. Physiother Can 59:166–172.
22. Maitland C. 1977. Peripheral manipulation, 2nd ed. Butterworths: Sydney, New South Wales, Australia.
23. Grindstaff TL, Beazell JR, Sauer LD, et al. 2011. Immediate effects of a tibiofibular joint manipulation on lower extremity H-reflex measurements in individuals with chronic ankle instability. J Electromyogr Kinesiol 21:652–658.
24. Docherty CL, Gansneder BM, Arnold BL, et al. 2006. Development and reliability of the ankle instability instrument. J Athl Train 41:154–158.
25. Martin RL, Irrgang JJ, Burdett RG, et al. 2005. Evidence of validity for the Foot and Ankle Ability Measure. Foot Ankle Int 26:968–983.
26. Bennell K, Talbot R, Wajswelner H, et al. 1998. Intra-rater and inter-rater reliability of a weight-bearing lunge measure of ankle dorsiflexion. Aust J Physiother 44:175–180.
27. Robinson RH, Gribble PA. 2008. Support for a reduction in the number of trials needed for the Star Excursion Balance Test. Arch Phys Med Rehabil 89:364–370.
28. Gribble PA, Hertel J. 2003. Considerations for normalizing measures of the Star Excursion Balance Test. Meas Phys Educ Exer Sci 7:89–100.
29. Landrum EL, Kelln BM, Parente WR, et al. 2008. Immediate effects of anterior-to-posterior talocrural joint mobilization after prolonged ankle immobilization: a preliminary study. J Man Manip Ther 16:100–105.
30. Kaltenborn F. 1999. Manual mobilization of the joints, 5th ed. Minneapolis, MN: OPTA.
31. Wyrwich KW, Tierney WM, Wolinsky FD. 1999. Further evidence supporting an SEM-based criterion for identifying meaningful intra-individual changes in health-related quality of life. J Clin Epidemiol 52:861–873.
32. Beaton DE, Bombardier C, Katz JN, et al. 2001. A taxonomy for responsiveness. J Clin Epidemiol 54:1204–1217.
33. Perneger TV. 1998. What's wrong with Bonferroni adjustments. BMJ 316:1236–1238.
34. Hedges LV, Olkin I. 1985. Statistical methods for research synthesis. Academic Press Inc.
35. Cohen J. 1988. Statistical power analysis for behavior science, 2nd ed. Hillsdale, NJ: Lawrence Erlbaum Association.
36. McKeon PO, Medina JM, Mattacola CG, et al. 2011. Finding context: a new model for interpreting clinical evidence. Int J Athl Ther Train 16:10–13.

37. McKeon PO, Ingersoll CD, Kerrigan DC, et al. 2008. Balance training improves function and postural control in those with chronic ankle instability. Med Sci Sport Exer 40:1810–1819.
38. Hoch MC, Silkman CL. 2010. Clinical research review: balance training improves postural control and function in those with chronic ankle instability. Athl Ther Today 15: 9–11.
39. Hoch MC, Staton GS, McKeon PO. 2011. Dorsiflexion range of motion significantly influences dynamic balance. J Sci Med Sport 14:90–92.
40. Robinson R, Gribble P. 2008. Kinematic predictors of performance on the Star Excursion Balance Test. J Sport Rehabil 17:347–357.
41. Green T, Refshauge K, Crosbie J, et al. 2001. A randomized controlled trial of a passive accessory joint mobilization on acute ankle inversion sprains. Phys Ther 81:984–994.
42. Hale SA, Hertel J, Olmsted-Kramer LC. 2007. The effect of a 4-week comprehensive rehabilitation program on postural control and lower extremity function in individuals with chronic ankle instability. J Orthop Sport Phys Ther 37:303–311.