Journal of Bodywork & Movement Therapies 23 (2019) 194–201

Contents lists available at ScienceDirect

Journal of Bodywork & Movement Therapies

journal homepage: www.elsevier.com/jbmt

PREVENTION AND REHABILITATION: PILOT STUDY

Joint mobilization and static stretching for individuals with chronic ankle instability – A pilot study

Chase M. Feldbrugge [a], Megan M. Pathoomvanh [a], Cameron J. Powden [b, *], Matthew C. Hoch [c]

[a] Old Dominion University, School of Physical Therapy and Athletic Training, 3120 Health Sciences Building, Norfolk, VA, 23529, USA
[b] Indiana State University, Department of Applied Medicine and Rehabilitation, North 5th Street, Terre Haute, IN, 47809, USA
[c] University of Kentucky, Division of Athletic Training, 206A Charles T. Wethington Jr Building, Lexington, KY 40536, USA

A R T I C L E I N F O

Article history:
Received 26 April 2017
Received in revised form
1 September 2017
Accepted 8 September 2017

A B S T R A C T

Objective: To complete preliminary analysis regarding the effects joint mobilization timing during a 4-week calf stretching intervention on clinician-oriented and patient-oriented outcomes in individuals with chronic ankle instability (CAI). Additionally, a secondary objective was to examine the combined effect of joint mobilization and calf stretching.
Design: Randomized two-group pretest posttest design.
Setting: Laboratory.
Participants: Ten adults (age = 24.4 ± 4.7years; height = 172.1 ± 11.3 cm; weight = 76.2 ± 17.1 kg) with self-reported CAI participated.
Interventions: Participants completed outcome measures at three collection sessions (baseline, pre-intervention, and post-intervention). Participants were randomized into either into an early-mobilization or late-mobilization group in which they completed a joint mobilization intervention during the first or last 2 weeks of a 4-week calf stretching intervention.
Main outcome measures: Outcome measures included: dorsiflexion ROM, dynamic postural control, single-limb postural control, Disablement in the Physically Active Scale (DPA), Foot and Ankle Ability Measure (FAAM), and Fear-Avoidance Beliefs Questionnaire (FABQ). Wilcoxon Sign Rank Tests examined pre-intervention to post-intervention differences for each dependent variable. Mann-Whitney U tests examined differences between early-mobilization and late-mobilization groups. Alpha was set *a priori* at $p < .05$.
Results: No significant differences were identified between early-mobilization and late-mobilization groups at post intervention ($p > .095$). FAAM-Activities of Daily Living, DPA, FABQ-Physical Activity, and dorsiflexion ROM were significantly improved at post-intervention compared to pre-intervention ($p < .047$). No other significant differences were identified between pre-intervention and post-intervention ($p > .057$).
Conclusion: Preliminarily results suggest the timing of joint mobilization when used in conjunction with calf stretching does not effect treatment efficacy. However, the combination of joint mobilization and calf stretching can improve dorsiflexion ROM and self-reported function in individuals with CAI. Improvements from the combined intervention are similar to previously reported effects of isolated joint mobilization or stretching.

1. Introduction

Ankle sprains are one of the most common musculoskeletal injuries in sport (Doherty et al., 2014; Fong et al., 2007). Despite creating lifestyle-limiting symptoms, ankle sprains are often considered innocuous injuries because many patients return to sport activity within 7 days (McKeon et al., 2014). Following an acute ankle sprain, approximately 40% of patient will develop chronic ankle instability (CAI) (Anandacoomarasamy and Barnsley, 2005). CAI is characterized by repetitive bouts of instability, ankle trauma, and functional detriments (Hertel, 2002). CAI is also associated with an increased risk of osteoarthritis (Valderrabano et al., 2006) and

* Corresponding author. Indiana State University, Department of Applied Medicine and Rehabilitation, North 5th Street, Terre Haute, IN, 47809, USA.
E-mail address: Cameron.powden@indstate.edu (C.J. Powden).

https://doi.org/10.1016/j.jbmt.2017.09.026
1360-8592/

decreased physical activity (Hubbard-Turner and Turner, 2015). Therefore, the impairments associated with CAI need to be addressed to prevent the long-term health detriments associated with this condition.

People with CAI have demonstrated a multitude of structural and functional impairments; as well as, self-reported activity limitations and participation restrictions (Hertel, 2002; Houston et al., 2015a,b). A common impairment is reduced dorsiflexion range of motion (DROM) (Hoch et al., 2012a,b). DROM deficits may contribute to the dynamic postural control deficits commonly identified on the anterior reach direction of the Star Excursion Balance Test (SEBT-AR) (Hoch et al., 2011; Hoch et al., 2012a,b). DROM and postural control may contribute to the self-perceived disablement or decreased health-related quality of life (HRQL) reported by individuals with CAI (Houston et al., 2015a,b). HRQL deficits have been primarily identified using ankle-specific patient-reported outcomes (PROs) such as the Foot and Ankle Ability Measure (FAAM). However, deficiencies have also been reported on generic PROs designed for physically active populations and dimension-specific PROs which focus on fear of re-injury (Houston et al., 2015a,b). Overall, structural and functional impairments coupled with decreased HRQL highlight the need to explore and develop treatment options for CAI.

Anterior-to-posterior (AP) talocrural joint mobilizations are commonly used to improve DROM in people with CAI. Single and serial applications of AP joint mobilization have improved DROM in those with CAI (Hoch et al., 2012a,b; McKeon and Wikstrom, 2015). Furthermore, joint mobilization is theorized to enhance sensorimotor function by stimulating sensory receptors around the talocrural joint (Hoch and McKeon, 2011). This theory has been supported by static and dynamic postural control improvements following joint mobilization (Hoch et al., 2012a,b; Hoch and McKeon, 2011; McKeon and Wikstrom, 2015). Several investigations have also identified improvements in ankle-specific PRO measures following joint mobilization indicating these interventions have patient perceived effects (Hoch et al., 2012a,b; McKeon and Wikstrom, 2015). Overall, talocrural joint mobilizations can enhance DROM, postural control, and HRQL in individuals with CAI, which supports incorporating this treatment into the rehabilitation paradigm for CAI.

Calf stretching is also a common treatment to improve DROM (Dinh et al., 2011; Kang et al., 2015; McKeon and Wikstrom, 2015). Calf stretching has demonstrated the ability to improve DROM and HRQL in people with CAI (McKeon and Wikstrom, 2015). It is logical that calf stretching could be used in combination with joint mobilization to address the impairments associated with CAI. The combination of these treatments has increased DROM in healthy individuals with DROM deficits (Kang et al., 2015). However, there is a dearth of evidence regarding the effects of this treatment combination for CAI. It is also unclear if implementing these treatments in a particular sequence can maximize treatment effects. No studies have explored if improving arthrokinematic motion and soft-tissue restriction concurrently is more beneficial than layering treatments. For example, creating initial DROM improvements by addressing soft-tissue restrictions may facilitate greater overall gains when arthrokinematic motion is addressed later in the rehabilitation process. Therefore, the purpose of this study was to pilot test the comparative effects of joint mobilization timing when used in conjunction with a 4-week calf stretching intervention on DROM, static and dynamic postural control, and HRQL in patients with CAI. Through this study design, we are also able to examine the combined effects of joint mobilization and calf stretching on the aforementioned treatment outcomes. We hypothesized the timing of joint mobilization would affect treatment outcomes. In addition, we hypothesized that DROM, postural control, and HRQL would improve following the 4-week intervention when examined across all subjects.

2. Methods

2.1. Design

A randomized, two-group pretest posttest design was implemented in a pilot sample of subjects with CAI to gain preliminary information regarding the effect of joint mobilization timing when used with calf stretching. As a secondary purpose, the overall effects of combining these interventions was evaluated. Individuals were randomized at the start of the 4-week intervention to either receive joint mobilizations during the first 2 weeks (early-mobilization) or the last 2 weeks (late-mobilization). The independent variable was time (baseline, pre-intervention, and post-intervention) and group (early-mobilization, late-mobilization). The dependent variables were DROM, static and dynamic postural control, and self-reported function.

2.2. Participants

Ten physically active individuals with self-reported CAI (5 females; age = 24.20 ± 4.32years; height = 171.56 ± 10.14 cm; weight = 80.01 ± 24.15 kg) volunteered to participate. Participants were recruited using advertisements posted throughout a large public university. To be included, participants had to be between the ages of 18–50 years, score ≥24 on Godin Leisure-Time Exercise Questionnaire (Godin and Shephard, 1985), exhibit a self-reported history of ≥1 ankle sprain and ≥2 episodes of "giving way" in the past 3 months, as well as answering "yes" to ≥5 questions of Ankle Instability Instrument (Docherty et al., 2006), and score ≤24 on Cumberland Ankle Instability Tool (Gribble et al., 2014; Hiller et al., 2006). 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 modification of activities of daily living for ≥1 day. An episode of "giving way" was classified as an incident in which the rearfoot suddenly inverted, felt weak, or lost stability with no resulting pain or disability. Participants were excluded if they had a history of an ankle sprain in the previous 6 weeks, history of lower extremity injury within the past 6 months, history of lower extremity surgery, or a condition that could affect balance (vestibular disorder, neuropathies, diabetes, etc.) (Gribble et al., 2014). Assessment of inclusion and exclusion criteria was completed by an investigator that was blinded to group assignments until the completion of the study. Prior to enrollment, all participants completed an informed consent document approved by the university's institutional review board.

2.3. Procedure

Participants reported to the laboratory for three data collection sessions. Baseline and pre-intervention sessions were separated by 1 week and were used to determine the minimal detectable change (MDC) of the dependent variables. Immediately following the pre-intervention session, participants were randomized into groups and began the intervention phase. Randomization was completed using sealed opaque envelopes created by an individual not involved with the study. Group assignment was determined using a random number generator prior to the initiation of the investigation and subjects were assigned to their respective group sequentially. The participants were unaware that there were two potential treatment sequences. The post-intervention session occurred within 24–48 h following the 4-week intervention. During each session, participants first completed PRO measures including: the

Disablement in the Physically Active Scale (DPA) (Vela and Denegar, 2010), FAAM Activities of Daily Living (FAAM-ADL) and Sport (FAAM-Sport) subscales (Martin et al., 2005), and the Fear Avoidance Belief Questionnaire (FABQ) (Inrig et al., 2012) in random order using an interactive portable document file format on a tablet. Participants then completed a series of clinician-oriented outcomes in a counter-balanced order. Counter-balancing was completed using a Latin Square approach. Clinician-oriented outcomes included: the WBLT to measure DROM, quiet single-limb stance on a force plate to measure static postural control, and the SEBT-AR to assess dynamic postural control. Three athletic trainers with 1–10 years of experience collected outcome measures and were blinded group. The primary investigator held a 3-h training session with the research team to ensure consistent application of each measure.

Intervention. The participants completed a 4-week intervention that consisted of a home-stretching program and joint mobilization treatment. The home-stretching program consisted of static stretching exercises performed daily over the 4-week intervention. The stretching intervention included two stretches (Figs. 1 and 2) targeted at the gastrocnemius-soleus complex that were completed with the ball of the foot on a half foam roller. One was completed with the knee in full extension and the other with the knee slightly bent. Each of these stretches were performed for 30s and repeated three times (McKeon and Wikstrom, 2015). Lastly, participants were given an intervention log to track their daily compliance with the home intervention.

Participants also completed six joint mobilization treatments which were nested within the 4-week intervention period. An equal number of participants were randomized to receive joint mobilization during either the first two weeks (early-mobilization) or last two weeks (late-mobilization) of the intervention. During

Fig. 1. Straight-leg gastrocnemius-soleus complex stretch performed on half foam roller with flat side on the ground. All participants instructed to keep heel on the ground with forefoot on the foam roller.

Fig. 2. Bent-knee gastrocnemius-soleus complex stretch performed on half foam roller with flat side on the ground. All participants instructed to keep heel on the ground with forefoot on the foam roller.

each session, 1-min of talocrural joint traction was followed by 4, 2-min sets of Maitland Grade III AP joint mobilizations with 1-min of rest between each set (Hoch et al., 2012a,b; Landrum et al., 2008). A total of 9 min of treatment was completed during each session. Participants were positioned supine on a table with the involved foot extended over the edge. The clinician positioned their stabilization hand superior to the talocrural joint while the mobilization hand was positioned with its web space over the talus (Fig. 3). The joint mobilization technique consisted of 1-s oscillations between mid- and end-range of the articular joint motion (Hoch et al., 2012a,b; Landrum et al., 2008). Two credentialed athletic trainers with 2–3 years of experience performed the joint mobilization intervention and were blinded to all outcome measures. These clinicians received training prior to performing joint mobilization treatments by an investigator with 10 years of experience.

Dorsiflexion Range of Motion. The WBLT was performed using the knee-to-wall principle to determine DROM (Bennell et al., 1998). Participants performed one practice trial and three analysis trials on the involved limb. The participant was instructed to lunge forward with the involved limb in an attempt to make knee contact with the wall. The uninvolved limb was placed beside the involved in a comfortable position and hands could be placed on the wall for balance. Participants had to maintain heel and knee contact before being able to progress away from the wall. Participants initially progressed away from the wall in 1 cm increments until the first lunge which the heel lifted or the knee failed to contact the wall. Following the first failed lunge, the foot was adjusted on the tape measure in smaller increments. Maximum dorsiflexion was measured from the great toe to the wall at the furthest point in which heel and knee contact could be maintained. The average of the three trials was calculated and used for statistical analysis. Very

Fig. 3. Joint mobilizations. Participants positioned on a table with involved foot extended over the edge and the clinician positioned their stabilization hand superior to the talocrural joint while the mobilization hand was positioned with its web space over the talus.

strong intrarater and interrater reliability have been recorded for the WBLT (Powden et al., 2015).

Static Postural Control. Quiet single limb stance on a force plate (AccuSway Plus balance platform, Advanced Mechanical Technology, Inc., Watertown, MA) was used to assess static postural control. Before testing, each participant's foot was centered on the force plate using a grid system. Participants then completed one practice trial and three analysis trials each lasting 10-s in length. Instructions were to remain still with their hands on their hips and the uninvolved limb positioned in approximately 45° of knee flexion and 30° of hip flexion. If participants were unable to maintain the standing position, touched down, or opened eyes during a closed eyes trial, the trial was discarded and repeated. Center of pressure (CoP) data were captured and exported using Balance Clinic software (Version 1.0, Advanced Mechanical Technology). CoP data were separated into its anterior-posterior (AP) and medial-lateral (ML) components and analyzed separately as the time-to-boundary (TTB) variables TTB mean minima (TTB mean) and standard deviation of mean minima (TTB SD) (Hertel et al., 2006). TTB Mean estimates the time an individual has to make postural corrections based on the location and velocity of CoP data points. TTB SD represents the theoretical number of solutions used to maintain single-limb stance throughout the 10-s trial. Higher TTB Mean and TTB SD values indicate great postural control (Hertel et al., 2006). The majority of TTB variables have demonstrated moderate to good (ICC = 0.40–0.75) intersession reliability (Hoch et al., 2014).

Dynamic Postural Control. The SEBT-AR was used to quantify dynamic postural control and was based on a previously described method (Gribble et al., 2013). Participants were instructed to perform maximal reaches with the uninvolved limb and lightly toe touch the tape measure and return to starting position. If the hands did not remain on hips, the position of the stance foot was not maintained, the heel lifted off the ground, or the participant lost balance, the trial was discarded and repeated. Participant performed four practice trials followed by three analysis trials. Reach distances were measured in centimeters and normalized to leg length. Leg length was measured from the anterior superior iliac crest to the medial malleolus. The SEBT-AR demonstrated strong intrarater and interrater reliability (ICC = 0.92) (Gribble et al., 2013).

Patient-Oriented Outcomes. Four PRO measures were utilized to capture HRQL including the DPA, FAAM-ADL, FAAM-Sport, and FABQ. The DPA is a generic measure of HRQL used in the evaluation of physically active individuals with musculoskeletal injuries (Vela and Denegar, 2010). DPA scores range from 0 to 64 with higher scores representing functional limitations and decreased well-being (Vela and Denegar, 2010). The FAAM is a region-specific measure of health and function in individuals with a range of ankle and foot musculoskeletal conditions (Martin et al., 2005). The FAAM encompasses 29 items across two subscales to assess physical function related to activities of daily living (FAAM-ADL) and sport (FAAM-Sport) (Martin et al., 2005). Scores on all FAAM instruments range from 0 to 100% with 100% representing full function (Martin et al., 2005). The FABQ is a dimension-specific measure of health, which evaluates fear-avoidance beliefs (Inrig et al., 2012). The FABQ is comprised of two subscales: physical activity (PA) and work. The FABQ-PA was used in this study and scores range from 0 to 24 with higher scores indicating increased fear-avoidance beliefs (Inrig et al., 2012). All PRO instruments have previously identified HRQL deficiencies in people with CAI (Houston et al., 2015a,b) and have demonstrated moderate to high test-retest reliability (ICC≥0.7) (Inrig et al., 2012; Martin et al., 2005; Vela and Denegar, 2010).

2.4. Data analysis

Differences in demographic variables between groups were evaluated using Mann-Whitney U tests. Descriptive statistics were calculated for dependent variables at each time point. MDC scores were calculated to determine the minimal change required after the intervention to exceed measurement error. MDC scores were calculated using the formula: $SEM \times \sqrt{2}$ (Beaton et al., 2001).

Mann-Whitney U tests were used to examine differences between early-mobilization and late-mobilization groups. To evaluate the secondary objective, Wilcoxon Signed Rank tests were used to examine pre-intervention to post-intervention differences for all dependent variables regardless of group. Alpha level was set *a priori* at $p<.05$ for all analyses. Change scores from pre-intervention to post-intervention for each group were used to calculate non-parametric ES for each dependent variable using the formula: $r = z/\sqrt{N}$ (Fritz et al., 2012). ES were interpreted as weak (<0.30), moderate (0.30–0.49), and strong (≥0.50) (Fritz et al., 2012). Non-parametric analyses were completed due to the violation of normality in some of the dependent variables. Means and standard deviations were used to calculate post hoc estimates of sample size, using an alpha level of 0.05 and power of 0.90, to determine if a larger trial would be feasible for further exploring these objectives. Lastly, the determination of the number of responders was assessed for each outcome by comparing the calculated MDCs with the pre-intervention to post-intervention change score for each participant. All analyses were completed with SPSS v23.0 (SPSS, Inc., Chicago, IL, USA) and Excel 2016 (Microsoft Inc., Redmond, WA, USA).

3. Results

Participant demographics and inclusion criteria can be found in Table 1. There were no differences in demographic data between groups ($p > .95$). Means, standard deviations, MDCs, ESs, estimated

Table 1
Participant demographics and inclusion criteria.

	Early-Mobilization	Late-Mobilization	Overall
	n = 5	n = 5	N = 10
Age (yrs)	23.80 ± 3.90	25.00 ± 5.79	24.4 ± 4.7
Height (cm)	169.90 ± 5.98	174.28 ± 15.49	172.1 ± 11.3
Mass (kg)	69.22 ± 13.09	83.10 ± 19.00	76.2 ± 17.0
Godin Leisure-Time Exercise Questionnaire	63.40 ± 11.06	63.4 ± 26.88	63.4 ± 19.4
Previous Ankle Sprains	7.80 ± 9.73	7.8 ± 7.22	7.8 ± 8.1
Episodes of "Giving Way" in Past 3 Months	4.20 ± 2.17	5.00 ± 5.57	4.6 ± 4.0
Ankle Instability Instrument	5.90 ± 1.64	6.40 ± 0.89	6.1 ± 1.3
Cumberland Ankle Instability Tool	19.60 ± 1.82	16.90 ± 3.63	18.2 ± 3.1

sample size, and number of responders for all dependent variables are presented in Tables 2–4. All participants completed each session of the joint mobilization intervention. One participant did not return their home intervention log. Based on the nine returned intervention logs, participants were 86.64% compliant overall, with a low individual compliance of 50% and a high of 100%. Seven out of the nine participants were over 90% compliant with the home stretching intervention.

The evaluation of differences between groups identified significant differences between groups at pre-intervention for eyes open TTB Mean AP, eyes open TTB SD AP and eyes closed TTB SD AP at baseline. No other significant differences were identified between groups at pre-intervention or post-intervention ($p > .056$). ES for between group comparisons ranged from 0.00 to 0.40 with 13 ES classified as weak and one classified as moderate.

When the groups were pooled, there were no significant differences between baseline and pre-intervention ($p > .134$) outcomes. Wilcoxon Signed Ranked Tests demonstrated that FAAM-ADL, DPA, FABQ-PA, and WBLT scores significantly improved at post-intervention compared to pre-intervention ($p < .047$). No other significant differences were identified between pre-intervention and post-intervention ($p > .057$). ES ranged from 0.10 to 0.56 with six classified as weak, six as moderate, and two as strong.

4. Discussion

The purpose of this study was to complete a pilot analysis regarding the effect of joint mobilization timing during a 4-week joint mobilization and calf stretching program on DROM, static and dynamic postural control, and self-perceived function in individuals with CAI. The main finding of this study was that there were no significant differences between the early-mobilization and late-mobilization groups at post-intervention. This finding is supported by primarily weak effect sizes (<0.001 to 0.40) and relatively large post hoc sample size estimates suggesting that a larger trial is likely unwarranted and unfeasible. However, the combined effects of the joint mobilizations and calf stretching intervention demonstrated improvements in DROM as well as self-reported ankle

Table 2
Means ± standard deviations and minimal detectable change scores for clinician-oriented measures (n = 10).

Dependent Variable	Baseline	Pre-Intervention	Post-Intervention	*p*	Pre-Post ES; Sample Size Estimate	Group Post ES; Sample Size Estimate
WBLT (cm)						
MDC = 0.55 Responders = 7						
Early-Mobilization	10.53 ± 4.04	10.68 ± 3.46	12.29 ± 2.46			
Late-Mobilization	9.08 ± 4.61	8.98 ± 3.91	10.19 ± 3.48			
Overall	9.80 ± 4.16	9.80 ± 3.60	11.20 ± 3.05	.013	0.56; 11	0.26; 110
SEBT-AR (%)						
MDC = 4.75 Responders = 3						
Early-Mobilization	71.62 ± 11.31	75.06 ± 8.52	76.8 ± 7.61			
Late-Mobilization	70.89 ± 7.84	71.07 ± 7.19	73.39 ± 5.57			
Overall	71.20 ± 9.02	73.00 ± 7.72	75.00 ± 7.00	.074	0.40; 14	0.21; 226
DPA						
MDC = 6.41 Responders = 5						
Early-Mobilization	9.00 ± 7.52	12.80 ± 6.38	10.60 ± 4.22			
Late-Mobilization	20.00 ± 8.6	19.20 ± 6.61	13.00 ± 5.24			
Overall	14.50 ± 9.57	16.00 ± 6.99	11.80 ± 4.66	.047	0.44; 22	0.16; 208
FAAM-ADL						
MDC = 4.30 Responders = 6						
Early-Mobilization	89.29 ± 10.28	90.95 ± 4.81	94.29 ± 3.71			
Late-Mobilization	87.62 ± 6.34	88.33 ± 6.54	93.09 ± 6.86			
Overall	88.45 ± 8.10	89.64 ± 5.59	93.69 ± 5.24	.033	0.48; 16	<0.00; 1100
FAAM-Sport						
MDC = 5.46 Responders = 6						
Early-Mobilization	79.37 ± 10.5	84.38 ± 5.85	88.13 ± 6.01			
Late-Mobilization	76.88 ± 10.73	78.12 ± 8.56	86.25 ± 12.02			
Overall	78.13 ± 10.10	81.25 ± 7.66	88.20 ± 9.02	.057	0.43; 21	0.02; 1330
FABQ-PA						
MDC = 1.71 Responders = 6						
Early-Mobilization	10.6 ± 3.65	10 ± 6.04	8.6 ± 5.37			
Late-Mobilization	10.4 ± 1.14	10.8 ± 2.95	6.8 ± 2.77			
Overall	10.50 ± 2.55	10.4 ± 4.50	7.7 ± 4.14	.023	0.51; 14	0.23; 296

ES = Effect Size, WBLT=Weight Bearing Lunge Test, SEBT-AR = Star-Exertion Balance Test Anterior Reach, DPA = Disablement of the Physically Active, FAAM=Foot and Ankle Ability Measure, ADL = Activities of Daily Living, FABQ=Fear-Avoidance Belief Questionnaire, MDC = Minimal Detectable Change.

Table 3
Means ± standard deviations and minimal detectable change scores for time-to-boundary variable(s) in the anterior-posterior and medial-lateral directions for eyes open conditions (n = 10).

Dependent Variable	Baseline	Pre-Intervention	Post-Intervention	*p*	Pre-Post ES; Sample Size Estimate	Group Post ES; Sample Size Estimate
TTB Mean AP						
MDC = 0.66 Responders = 7						
Early-Mobilization	5.46 ± 1.58	5.67 ± 2.11*	5.54 ± 1.5			
Late-Mobilization	3.62 ± 1.16	3.24 ± 0.97	4.64 ± 1.07			
Overall	4.54 ± 1.63	4.46 ± 2.01	5.09 ± 1.32	.241	0.26; 62	0.21; 112
TTB Mean ML						
MDC = 0.19 Responders = 5						
Early-Mobilization	1.9 ± 0.76	1.92 ± 0.72	1.8 ± 0.44			
Late-Mobilization	1.07 ± 0.21	1.12 ± 0.26	1.87 ± 0.70			
Overall	1.48 ± 0.69	1.52 ± 0.67	1.83 ± 0.55	.078	0.38; 49	0.07; 3628
TTB SD AP						
MDC = 0.64 Responders = 3						
Early-Mobilization	4.01 ± 1*	3.59 ± 1.75*	3.33 ± 1.17			
Late-Mobilization	2.24 ± 0.74	1.94 ± 0.63	2.65 ± 0.83			
Overall	3.13 ± 1.25	2.76 ± 1.51	2.99 ± 1.02	.445	0.17; 472	0.16; 118
TTB SD ML						
MDC = 0.34 Responders = 3						
Early-Mobilization	1.43 ± 0.67	1.43 ± 0.73	1.13 ± 0.27			
Late-Mobilization	0.69 ± 0.22	0.74 ± 0.29	1.51 ± 0.74			
Overall	1.06 ± 0.61	1.08 ± 0.64	1.32 ± 0.56	.285	0.24; 116	0.12; 114

* = Indicates significant difference between early-mobilization and late mobilization.
ES = Effect Size, TTB = Time-to-Boundary, Mean = Mean minima, SD=Standard Deviation of Mean Minima, AP = Anterior-Posterior, ML = Medial-Lateral, MDC = Minimal Detectable Change.

Table 4
Means ± standard deviations and minimal detectable change scores for time-to-boundary variable(s) in the anterior-posterior and medial-lateral directions for eyes closed conditions (n = 10).

Dependent Variable	Baseline	Pre-Intervention	Post-Intervention	*p*	Pre-Post ES; Sample Size Estimate	Group Post ES; Sample Size Estimate
TTB Mean AP						
MDC = 0.33 Responders = 5						
Early-Mobilization	2.27 ± 0.84	2.63 ± 1.26	2.53 ± 1.51			
Late-Mobilization	1.64 ± 0.59	1.67 ± 0.70	2.21 ± 0.94			
Overall	1.96 ± 0.76	2.15 ± 1.09	2.37 ± 1.20	.169	0.31; 60	0.12; 806
TTB Mean ML						
MDC = 0.08 Responders = 2						
Early-Mobilization	0.75 ± 0.31	0.77 ± 0.29	0.70 ± 0.23			
Late-Mobilization	0.77 ± 0.29	0.75 ± 0.25	0.76 ± 0.13			
Overall	0.76 ± 0.28	0.76 ± 0.25	0.73 ± 0.18	.646	0.10; 398	0.02; 506
TTB SD AP						
MDC = 0.34 Responders = 3						
Early-Mobilization	1.47 ± 0.64	1.78 ± 1.08	1.69 ± 1.36			
Late-Mobilization	0.96 ± 0.3	1.07 ± 0.51	1.34 ± 0.71			
Overall	1.22 ± 0.54	1.43 ± 0.88	1.52 ± 1.04	.508	0.15; 249	0.07; 502
TTB SD ML						
MCD = 0.18 Responders = 1						
Early-Mobilization	0.59 ± 0.26	0.53 ± 0.19	0.48 ± 0.11			
Late-Mobilization	0.93 ± 0.66	0.81 ± 0.4	0.72 ± 0.23			
Overall	0.76 ± 0.51	0.67 ± 0.32	0.60 ± 0.21	.445	0.17; 129	0.40; 32

TTB = Time-to-Boundary, Mean = Mean minima, SD=Standard Deviation of Mean Minima, AP = Anterior-Posterior, ML = Medial-Lateral, MDC = Minimal Detectable Change.

function, global well-being, and fear of re-injury in those with CAI. Moderate and strong ES (0.44–0.56) and reasonable sample size estimates were identified for a number of outcomes, indicating these improvements may be clinically meaningful. However, not all significant differences exceeded the associated MDC (FAAM-ADL and DPA). Overall, the combined effects of treatments appeared beneficial but it does not appear that timing of joint mobilizations influenced outcomes in those with CAI.

This study was the first to examine the effect of the timing of joint mobilization and stretching implementation on patient- and clinician-oriented outcomes. Although this was a pilot with small groups, we found limited evidence that overall treatment outcomes would differ between subjects who received both treatments concurrently at the onset of the intervention compared to individuals who performed static stretching for two weeks before receiving joint mobilization later in the intervention. Between groups comparisons were associated with primarily weak ES and large estimated sample sizes which supported the lack of significant differences. These findings indicate that joint mobilization timing may not effect outcomes within those with CAI. This investigation was the first step into the preliminary investigation regarding the interaction amongst treatments for those with CAI. Future investigations should consider other treatment interactions and timing scenar ios to determine optimal intervention delivery to produce robust patient outcomes.

A significant improvement in DROM (ES = 1.11 ± 0.72, mean difference = 1.4 cm, MDC = 0.55 cm, responders = 7, estimated sample size = 11) was identified following the intervention when the groups were pooled. These findings are consistent with previous literature on the isolated effects of joint mobilizations, which identified mean differences ranging from 1.24 to 2.23 cm (Hoch et al., 2012a,b; McKeon and Wikstrom, 2015). This provides evidence that coupling these treatment strategies can effectively improve DROM; however, the combined effects of this 4-week intervention may not exceed the isolated effects of 2 weeks of these treatments. While we identified a significant increase in DROM, we did not identify a significant increase in the SEBT-AR (ES = 0.40, mean difference = 2.0%, estimated sample size = 14). Furthermore, SEBT-AR differences were associated with moderate ES, changes that did not surpass the MDC (4.75%), and only three participants were categorized as responders. The mean SEBT-AR change identified in this study (2.0%) was less than the effects of an isolated 2-week joint mobilization intervention (mean difference = 2.5%) (Hoch et al., 2012a,b). This provides further evidence that combining joint mobilization and calf stretching may not result in greater treatment outcomes compared to the isolated effects of these techniques. While TTB improvements were identified following a single joint mobilization treatment (Hoch and McKeon, 2011), our results mirror the lack of changes in TTB identified following a 2-week joint mobilization intervention in people with CAI (Hoch et al., 2014). However, both single and repetitive bouts of joint mobilization and calf stretching have improved clinical measures of single limb postural control in a recent report (McKeon and Wikstrom, 2015). Lastly, it may be important to note that a majority of TTB responders were in the late mobilization group. For example, the late-mobilization group subjects comprised 5 of the 7 responders for TTB Mean AP with eyes open. Similar trends were identified in several other TTB measures, which may indicate that joint mobilization's effect on static postural control are short lasting or enhanced when initiated after calf stretching. Overall, there is conflicting evidence to support the theory that joint mobilizations can enhance static postural control and more research is needed in this area.

Previous CAI intervention studies have primarily evaluated region-specific function using PROs including the FAAM, Foot and Ankle Disability Instrument, and the CAIT (Cruz-Díaz et al., 2015; Hale et al., 2007; Hoch et al., 2012a,b; McKeon and Wikstrom, 2015). More specifically, investigations exploring the effects of joint mobilizations or calf stretching have demonstrated improvements in the FAAM-ADL and FAAM-Sport (Hoch et al., 2012a,b; McKeon and Wikstrom, 2015). While we found similar improvements with the FAAM-ADL, it appeared the combined treatment was only marginally more effective or comparable to 2-weeks of isolated joint mobilization or isolated calf stretching treatments (Hoch et al., 2012a,b; McKeon and Wikstrom, 2015). However, 60% of subjects were categorized as responders, which suggests a majority of subjects perceived this treatment combination as beneficial for ankle function. This indicates that the combined intervention positively improved region-specific function but the increased amount of treatment may not create a superior treatment effect compared to previous literature.

To our knowledge this is the first investigation to evaluate the effect of an intervention on global well-being and fear of re-injury in those with CAI. Participants initially reported decreased global well-being on the DPA and increased fear of re-injury on the FABQ at baseline which is consistent with previous findings (Houston et al., 2014). Following the intervention we found a significant reduction in fear of re-injury and improvements in global well-being (ES > 0.44). Addressing these factors is important as increased injury-related fear may be contributing to reports of physical activity limitations within those with CAI and sequentially lead to long term risk of other chronic conditions (Hubbard-Turner and Turner, 2015). Future research should continue this multidimensional approach to evaluating HRQL following rehabilitation and determine if improvements in physical activity levels or other related outcomes occur following intervention.

This investigation is not without limitations. We employed a randomized, two-group, pre-test posttest design that did not have a separate control group. The lack of a control group did not allow for a comparison to no treatment. To minimize the bias associated with the lack of a control group, we decided to examine and interpret the intervention's effect in multiple ways: statistical significance, effect sizes, and MDC values. Lastly, only the immediate effects of the intervention were examined and the duration of the effects are unknown. Also, another approach by Donovan et al. (2016), describe a rehabilitation paradigm of assessing and subsequently treating specific deficits of those with CAI. The application of this paradigm could potentially enhance the delivery of CAI care as individualized treatment programs could be implemented rather than a standard protocol approach.

5. Conclusion

This study provides preliminary evidence that joint mobilization timing may have no effect on patient outcomes when used in combination with calf stretching. Furthermore, these findings demonstrate that a future investigation regarding joint mobilization timing may not be warranted or feasible due to weak effect sizes and large post hoc estimates of sample size. The combined intervention of joint mobilization and calf stretching however, did resulted in improvements in DROM as well as self-perceived region-specific function, global well-being, and fear of re-injury in individuals with CAI. While our findings provide some support for integrating joint mobilization and calf stretching, the previously reported isolated effects of these interventions have been equally effective for several outcomes. The evaluation of the most effective time to integrate joint mobilizations and their combined effects with other treatment modalities should be investigated in a larger future research study.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Acknowledgments

The authors would like to acknowledge Lauren Welsh for her contributions to the study. She was pivotal in the delivery of the intervention.

References

Anandacoomarasamy, A., Barnsley, L., 2005. Long term outcomes of inversion ankle injuries. Br. J. Sports Med. 39 (3).
Beaton, D.E., Bombardier, C., Katz, J.N., Wright, J.G., 2001. A taxonomy for responsiveness. J. Clin. Epidemiol. 54 (12), 1204–1217 doi:S0895435601004073 [pii].
Bennell, K., Talbot, R., Wajswelner, H., Techovanich, W., Kelly, D., Hall, A., 1998. Intra-rater and inter-rater reliability of a weight-bearing lunge measure of ankle dorsiflexion. Aust. J. Physiother. 44 (3), 175–180.
Cruz-Díaz, D., Vega, R.L., Osuna-Pérez, M.C., Hita-Contreras, F., Martínez-Amat, A., 2015. Effects of joint mobilization on chronic ankle instability: a randomized controlled trial. Disabil. Rehabil. 37 (7), 601–610.
Dinh, N.V., Freeman, H., Granger, J., Wong, S., Johanson, M., 2011. Calf stretching in non-weight bearing versus weight bearing. Int. J. Sports Med. 32 (3), 205–210. https://doi.org/10.1055/s-0030-1268505.
Docherty, C.L., Gansneder, B.M., Arnold, B.L., Hurwitz, S.R., 2006. Development and reliability of the ankle instability instrument. J. Athl. Train. 41 (2), 154.
Doherty, C., Delahunt, E., Caulfield, B., Hertel, J., Ryan, J., Bleakley, C., 2014. The incidence and prevalence of ankle sprain injury: a systematic review and meta-analysis of prospective epidemiological studies. Sports Med. 44 (1), 123–140. https://doi.org/10.1007/s40279-013-0102-5.

Donovan, L., Hart, J.M., Saliba, S.A., Park, J., Feger, M.A., Herb, C.C., Hertel, J., 2016. Rehabilitation for chronic ankle instability with or without destabilization devices: a randomized controlled trial. J. Athl. Train. 51 (3), 233–251. https://doi.org/10.4085/1062-6050-51.3.09.

Fong, D., Hong, Y., Chan, L., Yung, P., Chan, K., 2007. A systematic review on ankle injury and ankle sprain in sports. Sports Med. 37 (1), 73–94.

Fritz, C.O., Morris, P.E., Richler, J.J., 2012. Effect size estimates: current use, calculations, and interpretation. J. Exp. Psychol. Gen. 141 (1), 2.

Godin, G., Shephard, R., 1985. A simple method to assess exercise behavior in the community. Can. J. Appl. Sport Sci. 10 (3), 141–146.

Gribble, P.A., Delahunt, E., Bleakley, C., Caulfield, B., Docherty, C.L., Fong, D.T., Wikstrom, E.A., 2014. Selection criteria for patients with chronic ankle instability in controlled research: a position statement of the International Ankle Consortium. J. Athl. Train. 49 (1), 121–127. https://doi.org/10.4085/1062-6050-49.1.14.

Gribble, P.A., Kelly, S.E., Refshauge, K.M., Hiller, C.E., 2013. Interrater reliability of the star excursion balance test. J. Athl. Train. 48 (5), 621–626. https://doi.org/10.4085/1062-6050-48.3.03.

Hale, S.A., Hertel, J., Olmsted-Kramer, L.C., 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. Sports Phys. Ther. 37 (6), 303–311.

Hertel, J., 2002. Functional anatomy, pathomechanics, and pathophysiology of lateral ankle instability. J. Athl. Train. 37 (4), 364–375.

Hertel, J., Olmsted-Kramer, L.C., Challis, J.H., 2006. Time-to-boundary measures of postural control during single leg quiet standing. J. Appl. Biomech. 22 (1), 67–73.

Hiller, C.E., Refshauge, K.M., Bundy, A.C., Herbert, R.D., Kilbreath, S.L., 2006. The Cumberland ankle instability tool: a report of validity and reliability testing. Arch. Phys. Med. Rehabil. 87 (9), 1235–1241.

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

Hoch, M.C., McKeon, P.O., 2011. Joint mobilization improves spatiotemporal postural control and range of motion in those with chronic ankle instability. J. Orthop. Res. 29 (3), 326–332. https://doi.org/10.1002/jor.21256.

Hoch, M.C., Mullineaux, D.R., Andreatta, R.D., English, R.A., Medina-McKeon, J.M., Mattacola, C.G., McKeon, P.O., 2014. Effect of a 2-week joint mobilization intervention on single-limb balance and ankle arthrokinematics in those with chronic ankle instability. J. Sport Rehabil. 23 (1), 18–26. https://doi.org/10.1123/jsr.2012-0125.

Hoch, M.C., Staton, G.S., McKeon, P.O., 2011. Dorsiflexion range of motion significantly influences dynamic balance. J. Sci. Med. Sport 14 (1), 90–92.

Hoch, M.C., Staton, G.S., Medina McKeon, J.M., Mattacola, C.G., McKeon, P.O., 2012b. Dorsiflexion and dynamic postural control deficits are present in those with chronic ankle instability. J. Sci. Med. Sport 15 (6), 574–579. https://doi.org/10.1016/j.jsams.2012.02.009. S1440–2440(12)00066-7 [pii].

Houston, M., Hoch, J., Gabriner, M., Kirby, J., Hoch, M., 2015a. Clinical and laboratory measures associated with health-related quality of life in individuals with chronic ankle instability. Phys. Ther. Sport 16 (2), 169–175. https://doi.org/10.1016/j.ptsp.2014.10.006.

Houston, M., Hoch, J., Hoch, M., 2015b. Patient-reported outcome measures in individuals with chronic ankle instability: a systematic review. J. Athl. Train. 50 (10), 1019–1033.

Houston, M.N., Van Lunen, B.L., Hoch, M.C., 2014. Health-related quality of life in individuals with chronic ankle instability. J. Athl. Train. 49 (6), 758–763. https://doi.org/10.4085/1062-6050-49.3.54.

Hubbard-Turner, T., Turner, M.J., 2015. Physical activity levels in college students with chronic ankle instability. J. Athl. Train.

Inrig, T., Amey, B., Borthwick, C., Beaton, D., 2012. Validity and reliability of the fear-avoidance beliefs Questionnaire (FABQ) in workers with upper extremity injuries. J. Occup. Rehabil. 22 (1), 59–70.

Kang, M.H., Lee, D.K., Kim, S.Y., Kim, J.S., Oh, J.S., 2015. The influence of gastrocnemius stretching combined with joint mobilization on weight-bearing ankle dorsiflexion passive range of motion. J. Phys. Ther. Sci. 27 (5), 1317–1318. https://doi.org/10.1589/jpts.27.1317.

Landrum, E.L., Kelln, C.B., Parente, W.R., Ingersoll, C.D., Hertel, J., 2008. Immediate effects of anterior-to-posterior talocrural joint mobilization after prolonged ankle immobilization: a preliminary study. J. Man. Manip. Ther. 16 (2), 100–105.

Martin, R.L., Irrgang, J.J., Burdett, R.G., Conti, S.F., Van Swearingen, J.M., 2005. Evidence of validity for the foot and ankle ability measure (FAAM). Foot Ankle Int. 26 (11), 968–983 doi:905748 [pii].

McKeon, J., Bush, H.M., Reed, A., Whittington, A., Uhl, T.L., McKeon, P.O., 2014. Return-to-play probabilities following new versus recurrent ankle sprains in high school athletes. J. Sci. Med. Sport 17 (1), 23–28.

McKeon, P.O., Wikstrom, E.A., 2015. Sensory-targeted ankle rehabilitation strategies for chronic ankle instability. Med. Sci. Sports Exerc. https://doi.org/10.1249/mss.0000000000000859.

Powden, C.J., Hoch, J.M., Hoch, M.C., 2015. Reliability and minimal detectable change of the weight-bearing lunge test: a systematic review. Man. Ther. 20 (4), 524–532.

Valderrabano, V., Hintermann, B., Horisberger, M., Fung, T.S., 2006. Ligamentous posttraumatic ankle osteoarthritis. Am. J. Sports Med. 34 (4), 612–620.

Vela, L.I., Denegar, C.R., 2010. The Disablement in the Physically Active Scale, part II: the psychometric properties of an outcomes scale for musculoskeletal injuries. J. Athl. Train. 45 (6), 630–641. https://doi.org/10.4085/1062-6050-45.6.630.