Acute effects of increased joint mobilisation treatment durations on ankle function and dynamic postural control in female athletes with chronic ankle instability

ABSTRACT

Background: Chronic ankle instability (CAI) is linked to mechanical and functional insufficiencies. Joint mobilisations are purported to be effective at treating these deficits.

Purpose: We examined the effect of different treatment durations of a Grade IV anterior-to-posterior ankle joint mobilisation on weight-bearing dorsiflexion range of motion (WB-DFROM), posterior talar glide (PG), and dynamic postural control in individuals with CAI.

Design: Randomized controlled clinical trial

Methods: Forty-eight female athletes (age 22.8±4.8yrs) with unilateral CAI participated in the study. Participants were randomly assigned to one of three treatment conditions: 30s, 60s, and 120s. Treatment was provided to the injured limb on 3 separate occasions set 48 hours apart, and consisted of a Maitland Grade IV anterior-to-posterior talar joint mobilisation based on the participant's initial group assignment. WB-DFROM, PG and the anterior (ANT), posteromedial (PM) and posterolateral (PL) reach directions of the Star Excursion Balance Test (SEBT) were measured bilaterally before and after each treatment. The uninjured limb acted as a control. Data was analysed using a two-way mixed model ANOVA and effect sizes calculated using hedge's *g*.

Results: Significant differences were detected following all treatment sessions for all outcome measures ($p \leq 0.001$) and between treatment groups following session 1, 2 and 3 for all outcome measures ($p \leq 0.001$). Effect sizes were 'very large' for all

treatment groups for WB-DFROM, PG and ANT. There was substantial variation in effect sizes for PM and PL measures.

Conclusions: Accessory mobilisations are an effective treatment for inducing acute changes in ankle motion and dynamic postural control in those with CAI, with higher treatment durations conferring greater improvements. This study adds clarity to the use of joint mobilisation treatments and will add to the current clinical practice strategy for those with CAI.

Key words Chronic Ankle Instability, Mobilization, Maitland, Dorsiflexion, Manual Therapy

What is known about the subject: Ankle sprains are the most common musculoskeletal disorder with up to 70% of those sustaining an ankle sprain developing symptoms of CAI. This is linked to several mechanical and functional insufficiencies including reduced DFROM, PG, and disruption to the transmission of afferent information to the sensorimotor system. Joint mobilisations demonstrate acute improvements in DFROM and PG in those with a history of ankle sprains, whilst also being shown to increase afferent input and dynamic balance. However, there is a paucity of research examining the acute effects of multiple treatments and the influence that treatment duration has on these outcomes.

What this study adds to existing knowledge: The study adds clarity to the use of joint mobilisations and adds to the current clinical practice and rehabilitative strategies for those with CAI.

INTRODUCTION

Ankle sprains are the most common musculoskeletal disorder, accounting for 22% of all sports injuries [11,15]. Despite the high prevalence and severity [4,11], they are often considered innocuous injuries and treated with limited time and resources [3]. However, ankle sprains have the highest recurrence rate of any musculoskeletal injury [1]. Up to 70% of those sustaining a single sprain report residual symptoms, including recurrent instability, additional ankle sprains and reduced functional capacity [45]. These negative antecedents form the primary characteristics of chronic ankle instability (CAI).

CAI is linked to several mechanical and functional insufficiencies [19]. The primary mechanical impairments include reduced dorsiflexion range of motion (DFROM) [10], reduced posterior talar glide [9] and increased anterior joint laxity [7]. Following an inversion ankle sprain the talus is subluxed creating an anterior positional fault, resulting in anterior ligament laxity, restrictions in posterior noncontractile tissue and observed decreases in DFROM [22]. The reduction in ROM may disrupt the transmission of afferent information to the sensorimotor system, contributing to the functional impairments associated with CAI [21]. Damage to ligamentous and capsular tissues causes partial deafferentation of mechanoreceptors resulting in a loss of somatosensory information to the CNS [20]. Changes in arthrokinematic function frequently results in alterations to sensory input, suggesting a synergistic relationship between mechanical and functional impairments [31].

Poor sensorimotor control and reductions in DFROM significantly increases the risk of lower extremity injury [19]. Interventions that address multiple aspects of impairment are necessary to alleviate the risks and limitations to activity experienced with CAI. As impairments are purported to be arthrogenic, interventions need to address the noncontractile tissue restrictions [9].

Joint mobilisations restore arthrokinematic movements that occur between joint surfaces, [13]. This is achieved through an increase in the extensibility of noncontractile tissues, increasing the extensibility of joint structures. Joint mobilisations also stimulate joint mechanoreceptors which improves the transmission of afferent information to the CNS [21,29]. Mobilisations consistently demonstrate acute improvements in DFROM and posterior talar glide in those with a history of ankle sprains [13,22,35]. The use of joint mobilisations to increase afferent input and their effect on dynamic balance and postural control has also been identified [8,23,24].

It is postulated that the acute magnitude of effect is influenced by treatment volume and duration. Treatment doses ranging from 30 to 120 seconds have been used by researchers to study the effects of mobilisations of the talus. These studies have shown that significant improvements can be elicited from these treatment durations [6,13,24,28]. Due to methodological differences an identification of the most efficacious treatment duration remains unclear. Given that injury treatment usually involves repeated therapy sessions, it is surprising that there is a paucity of research examining the acute effect of multiple treatments, particularly within the first week of management.

Therefore, we examined the effect of varying treatment durations within three treatment sessions on weight-bearing DFROM (WB-DFROM), posterior talar glide (PG), and dynamic postural control in individuals with CAI. We hypothesised that longer treatment durations would lead to greater improvements in outcome measures than shorter durations.

METHODS

Participants

A randomized single-blind clinical controlled trial was conducted. Enrolment in the study was conducted between October 2016 and March 2017. A total of 56 female athletes from a variety of collegiate level sports with self-reported CAI were screened for inclusion with 48 (mean ±SD: age 22.8 ±4.8yrs; height 171.1 ±6.1cm; mass 70.8 ±7.4kg) going on to complete the study. A complete female cohort were selected due to the established sex differences in dynamic and functional measures relating to physical performance [17]. Inclusion and exclusion criteria followed the International Ankle Consortium's standards for enrolling patients with CAI in controlled research [14]. Criteria consisted of a history of at least one ankle sprain within the last 12 months, resulting in a combination of pain, swelling and time lost or modification to normal function for ≥1 day [19]. The Cumberland Ankle Instability Tool (CAIT) was used to determine the pathology's extent, with a score of less than 24 out of 30 indicating the presence of the condition. Participants completed the CAIT bilaterally, allowing the uninjured extremity to be used as a control, as results were assessed to ensure participants had only unilateral symptoms. Participants were excluded if they reported a history of previous surgery, fracture, or acute musculoskeletal injury within the previous 3 months to either lower extremity [14]. The protocol adhered to the Helsinki

declaration and was approved by the institutional research ethics committee. All participants provided written consent prior to participation. Participants were also screened for any contraindications to mobilization [18].

Participants were randomly allocated to balanced treatment groups (n=16) of 30s, 60s or 120s using a computer-generated simple random allocation sequence (Fig. 1). Prior to testing and treatment intervention, baseline measures of limb length were obtained for all participants. Limb lengths were measured bilaterally using a limb measurement tape measure (Anatomical Tape Measure, Idass, UK) from the anterior superior iliac spine (ASIS) to the distal tip of the medial malleolus. The limb lengths were used to calculate normalised reach distances on the SEBT. Participants and the research team were blinded from the group allocation until after the first pre-intervention tests were completed. Pre and post measures of PG, WB-DFROM and dynamic postural control were collected for injured and uninjured limb in that order with participants barefoot, using previously described protocols [9]. Participants were blinded to all outcome measures which were taken for both limbs (injured and uninjured). The intervention and testing took place over 5 days and consisted of 3 separate treatment sessions (1, 2 and 3) with each including pre and post testing immediately before and after the applied mobilisation treatment. These were set 48 hours apart and scheduled for the same time of day to limit diurnal effects. All mobilization treatments and measurements were conducted by the same therapist with over 10 years of experience.

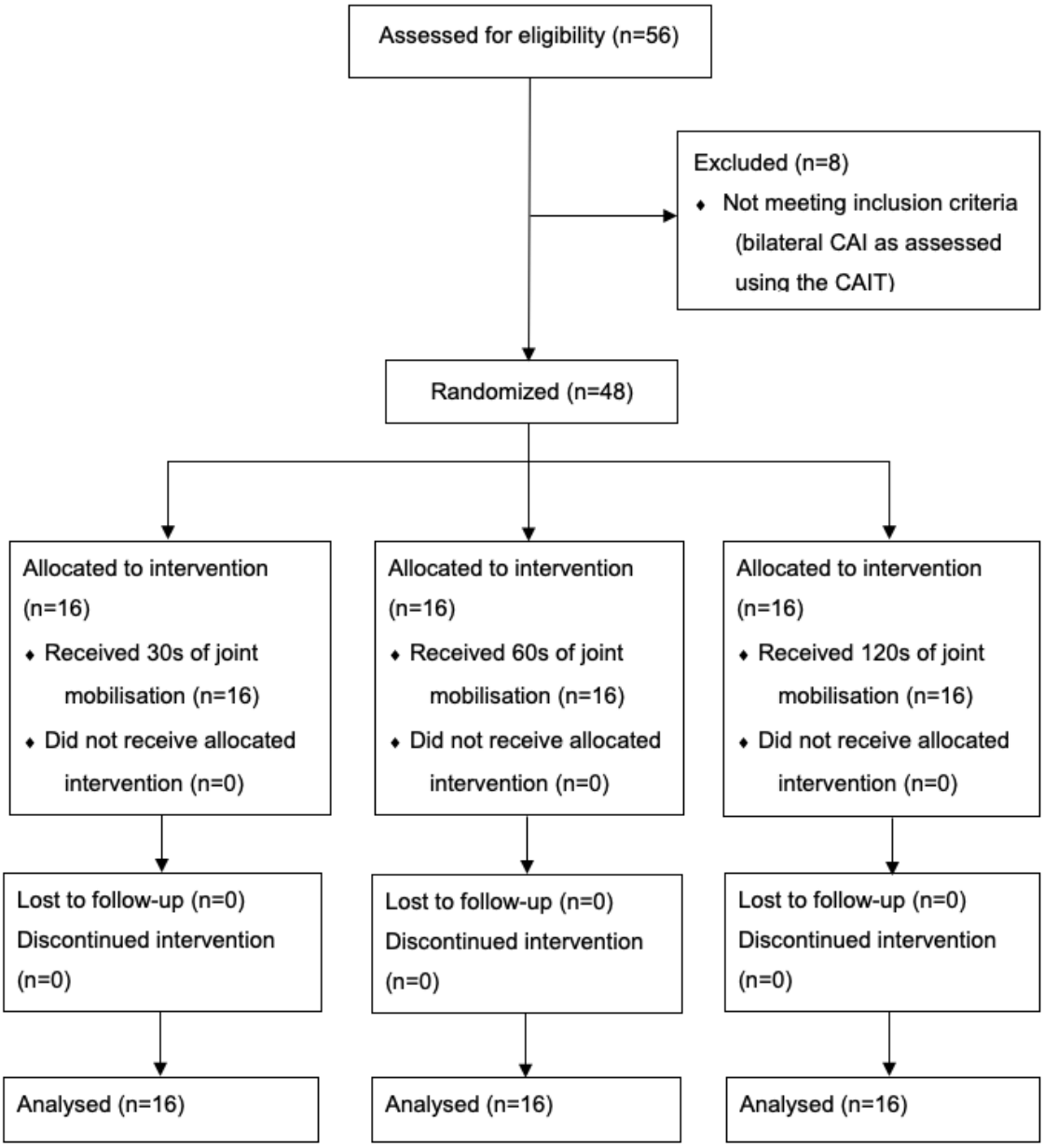

Fig.1. Flow diagram of participants. Abbreviations: CAI, chronic ankle instability; CAIT, Cumberland Ankle Instability Tool

Dorsiflexion range of motion

The weight-bearing lunge test (WBLT) measured WB-DFROM, utilising the knee-to-wall principle [9]. Participants stood facing a wall with the second toe and center of the heel perpendicular to the wall. Participants performed a lunge where the knee was flexed to contact the wall, whilst the heel remained planted on the floor. Foot position

was progressed away from the wall in 1cm increments until knee and heel contact could not be maintained. Smaller increments were then used to achieve the maximum distance from the wall. Maximum distance was measured using a limb measurement tape from the base of the wall to the tip of the great toe. Foot pronation and supination were monitored to ensure that movements occurred solely in the sagittal plane. This method produces a greater DFROM measurement than any other position [27] and demonstrates excellent reliability (ICC 0.98-0.99) [32].

Posterior talar glide

PG was assessed using the posterior talar glide test [9]. The test was performed with the participant seated on the plinth edge with knees at 90^0. A digital inclinometer (Jamar Plus Digital Goniometer) was secured just above the talocrural joint to measure knee flexion ROM. With the participant's foot in subtalar neutral, the talus was glided posteriorly. The first measurement was taken at initial soft tissue restriction and knee flexion angle recorded. The talus was then glided further until a firm capsular end feel was encountered and knee flexion angle again recorded. The angle of knee flexion provides an estimate of PG as when the talus can no longer be posteriorly displaced, the ankle can no longer be dorsiflexed and further knee flexion is limited [9]. Only a single measure for PG and WB-DFROM was taken to ensure there was no augmented effect from repeated assessment.

Star excursion balance test

Dynamic postural control was assessed using the anterior, posterior and posterolateral direction of the Star Excursion balance Test (SEBT) [20]. Equal halves of the length and width of the test foot were positioned in each quadrant of the SEBT and

marked to ensure accurate repositioning between trials[34]. Participants performed maximal reaches with the uninvolved limb followed by a single light toe touch on the tape measure. A trial was discarded if the participants' hands did not remain on the hips, stance foot position or heel contact was not maintained, or balance was lost. Distances were measured in centimeters, and normalised to leg length [16]. The average of three trials was used for analysis with each direction independently examined. This method has been shown to be highly reliable (ICC 0.84-0.92) [30].

Joint mobilisation intervention

The joint mobilisation was performed with the participant supine with foot positioned over the end of the plinth. The ankle was placed at 20^0 to plantar flexion to achieve the talocrural loose-packed position, allowing greater pressure application, which is transmitted to the posterior tissues [46]. The stabilising hand was placed proximal to the malleoli to stabilise the leg, whilst the mobilising hand cupped the anterior talus using the 1st web space. The talus was then glided posteriorly with downward force [26]. The foundation of the Maitland technique is a grading system that varies from I to IV. Grades I and II are primarily used to treat painful conditions and are performed before resistance is felt. This refers to the point at which a significant resistance to deformation is imposed by the tissue [43]. Grades III and IV are performed after resistance is felt and designed to restore ROM, with grade IV generally performed at the point of maximal resistance which determines the end of range [33]. The joint mobilisation selected for the current study was therefore defined as a grade IV, 1s rhythmic oscillation with translation taken to tissue resistance [28]. Oscillation speed was kept constant using a metronome. This technique was chosen in order to load and unload the tissue in a similar way to that which would occur functionally [2]. The

mobilisation was applied for 30s, 60s or 120s according to the participants initial group assignment.

Statistical analysis

The percentage improvement for each dependent variable was calculated for each individual treatment session (1, 2 and 3) prior to data analysis due to its clinical relevance and immediate accessibility to clinicians. Two-way mixed model ANOVAs ($p \leq 0.05$) were used to examine the differences in dependent variables. The independent variable was time (session 1, 2, 3), group (30s, 60s, 120s) and limb (injured, uninjured). Mauchly's sphericity test was conducted with the Greenhouse-Geisser adjustment included for all significant outputs. Post hoc comparisons were completed using Tukey's HSD in the presence of a group effect. Effect sizes (ES) were calculated between injured limb and control, and between groups, for all statistically significant results using a bias-corrected hedge's *g* with 95% confidence intervals. ES was interpreted as negligible (0-0.19), small (0.2-0.49), moderate (0.5-0.79), large (0.8-1.19) very large (1.2-1.99) and huge (≥2.0) [37].

RESULTS

At baseline, the groups were similar for all dependent variables ($p \geq 0.05$) (Table 1). Treatment dose and mean (±SD) percentage improvements for WB-DFROM, PG and SEBT reach directions following each treatment session are presented in Table 2. Effect sizes and 95% confidence intervals for injured limb versus control are shown in Figure 2, with effect sizes for treatment group differences shown in Figure 3. Significant differences were detected between groups following session 1, 2 and 3 for all outcome measures ($p \leq 0.001$).

	Treatment group		
Variables	**30s**	**60s**	**120s**
Participants (n)	16	16	16
Age (years)	23.2 ± 4.7	22.6 ± 5.8	22.6 ± 3.9
Height (cm)	169.8 ± 5.7	171.1 ± 6.5	171.6 ± 6.5
Mass (kg)	69.9 ± 7.7	71.9 ± 6.6	70.6 ± 8.1
BMI (kg/m^2)	24.5 ± 2.7	24.6 ± 1.9	23.9 ± 1.5
CAIT score (out of 30)			
Injured (CAI)	13.3	13.4	14.3
Uninjured (control)	27.3	26.6	27.7
WBLT (cm)			
Injured (CAI)	7.7 ± 1.9	8.8 ± 3.6	7.5 ± 2.1
Uninjured (control)	9.5 ± 1.5	11.9 ± 3.1	12.3 ± 4.6
PG (degrees)			
Injured (CAI)	5.9 ± 1.3	6.4 ± 1.4	5.4 ± 1.2
Uninjured (control)	9.4 ± 1.2	11.0 ± 2.4	10.2 ± 3.2
SEBT Anterior (normalised %)			
Injured (CAI)	51.7 ± 10.4	53.0 ± 6.5	58.6 ± 4.5
Uninjured (control)	60.9 ± 9.6	55.0 ± 1.5	63.2 ± 1.6
SEBT Posteromedial (normalised %)			
Injured (CAI)	70.8 ± 10.7	62.3 ± 12.7	75.6 ± 7.0
Uninjured (control)	71.4 ± 14.9	67.7 ± 6.9	78.2 ± 10.6
SEBT Posterolateral (normalised %)			
Injured (CAI)	78.4 ± 7.8	76.4 ± 8.9	80.6 ± 2.2
Uninjured (control)	79.7 ± 9.0	76.1 ± 3.6	85.9 ± 2.5

Table 1. Demographics and baseline characteristics (mean ± SD) of the study participants

Variables		Treatment group 30s		60s		120s	
		Injured	**Uninjured**	**Injured**	**Uninjured**	**Injured**	**Uninjured**
WB-DFROM	S1	**6.53 ± 1.35**	-0.24 ± 0.90	**9.80 ± 10.19**	0.87 ± 0.47	**15.09 ± 6.78[a]**	0.69 ± 0.87
	S2	4.56 ± 3.20[b]	0.96 ± 1.07	**8.61 ± 4.53[a]**	0.14 ± 0.63	**14.53 ± 6.60[ab]**	-0.74 ± 1.79
	S3	**4.68 ± 2.68[b]**	0.09 ± 1.36	**8.29 ± 4.04[a]**	-0.19 ± 1.41	**14.01 ± 4.96[ab]**	-1.17 ± 0.71
PG	S1	**5.94 ± 1.50**	0.12 ± 1.21	**7.89 ± 6.33**	0.67 ± 0.59	**14.97 ± 6.17[ab]**	0.25 ± 1.14
	S2	4.28 ± 3.39[b]	0.96 ± 1.20	**8.59 ± 4.20[a]**	0.22 ± 0.74	**13.28 ± 6.85[ab]**	-0.36 ± 1.23
	S3	**4.55 ± 2.82[b]**	0.05 ± 1.39	**8.72 ± 4.02[a]**	-0.42 ± 1.34	**13.83 ± 4.72[ab]**	-1.24 ± 0.82
SEBT ANT	S1	**1.13 ± 0.30[b]**	-0.11 ± 0.23	**2.13 ± 0.60[a]**	-0.14 ± 0.24	**3.02 ± 0.51[ab]**	0.02 ± 0.18
	S2	**1.62 ± 0.40[b]**	0.08 ± 0.43	**2.11 ± 0.23[a]**	0.21 ± 0.18	**3.46 ± 0.42[ab]**	0.02 ± 0.18
	S3	**1.83 ± 0.67[b]**	-0.40 ± 0.41	**2.48 ± 0.17[a]**	-0.12 ± 0.26	**3.77 ± 0.60[ab]**	0.02 ± 0.18
SEBT PM	S1	0.90 ± 0.26[b]	0.84 ± 0.29	**2.10 ± 0.79[a]**	1.55 ± 0.38	2.21 ± 0.54[a]	1.89 ± 0.58
	S2	0.88 ± 0.45[b]	1.21 ± 0.38	2.60 ± 0.53[a]	2.00 ± 0.26	2.46 ± 0.62[a]	2.16 ± 0.57
	S3	0.94 ± 0.45[b]	1.15 ± 0.21	2.71 ± 0.75[a]	2.54 ± 0.69	2.78 ± 0.20[a]	2.42 ± 0.33
SEBT PL	S1	**1.58 ± 0.36[b]**	1.05 ± 0.29	2.33 ± 0.39[a]	2.01 ± 0.59	2.64 ± 0.15[a]	2.26 ± 0.48
	S2	1.60 ± 0.93[b]	1.60 ± 0.21	2.47 ± 0.18[a]	2.11 ± 0.27	2.86 ± 0.38[a]	2.94 ± 0.96
	S3	1.55 ± 0.46[b]	1.31 ± 0.36	2.54 ± 0.53[a]	2.38 ± 0.34	2.82 ± 0.22[a]	2.61 ± 0.40

Table 2. Percentage improvement and standard deviation for weight-bearing dorsiflexion range of motion (WB-DFROM), posterior drawer, and anterior, posteromedial and posterolateral directions of the Star Excursion Balance Test (SEBT) within each session (S2, S2 and S3) across the study timeline.

[a] significantly greater when compared to the 30 second group; [b] significantly greater when compared to the 60 second group; bold font indicates significance when compared to control.

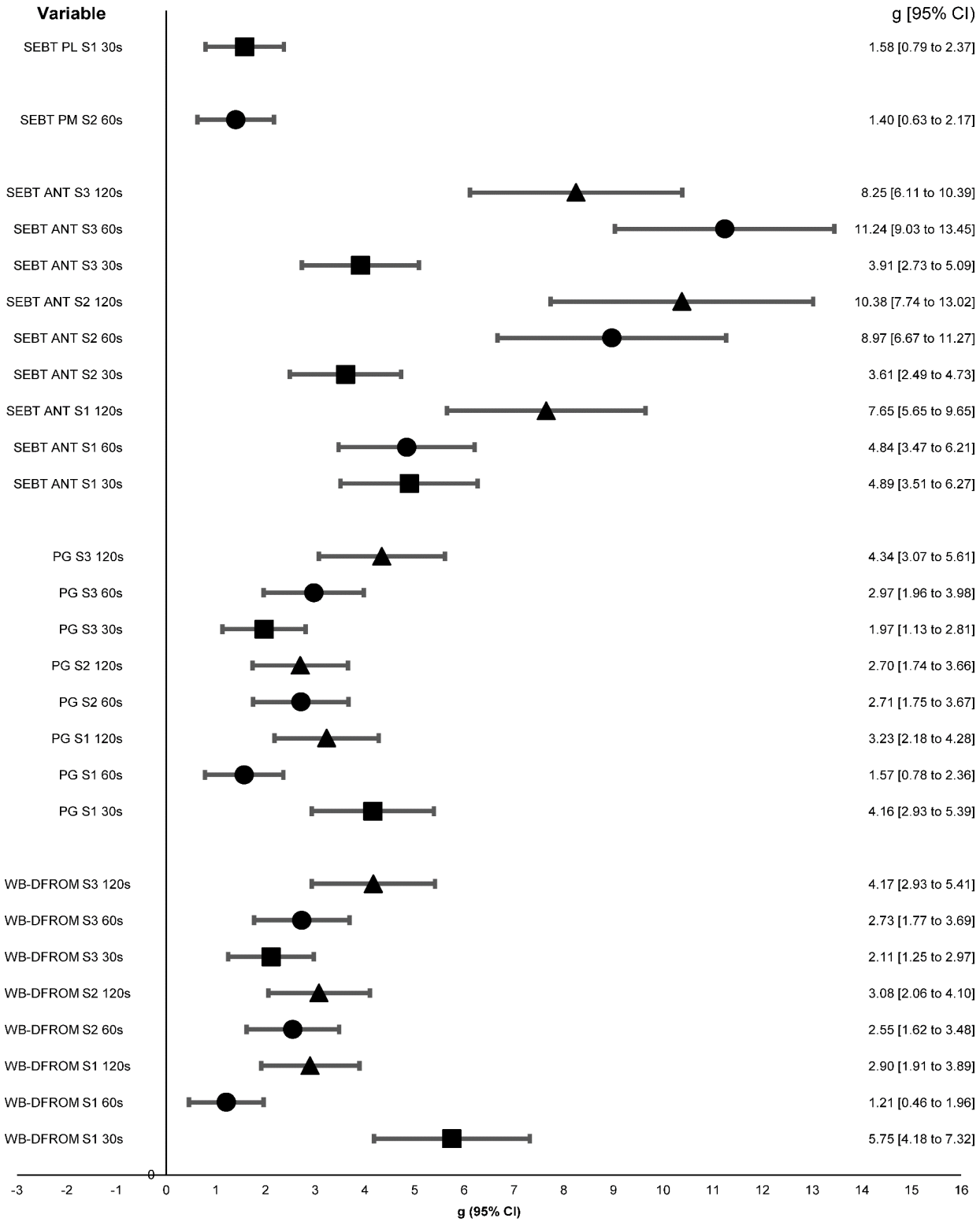

Figure 2. Forest plot ($g \pm 95\%$ CI) of injured versus uninjured limb for weight-bearing dorsiflexion range of motion (WB-DFROM), posterior drawer (PG), and anterior (ANT), posteromedial (PM) and posterolateral (PL) directions of the Star Excursion Balance Test (SEBT) across three testing sessions (S1, S2 and S3) for all statistically significant results.

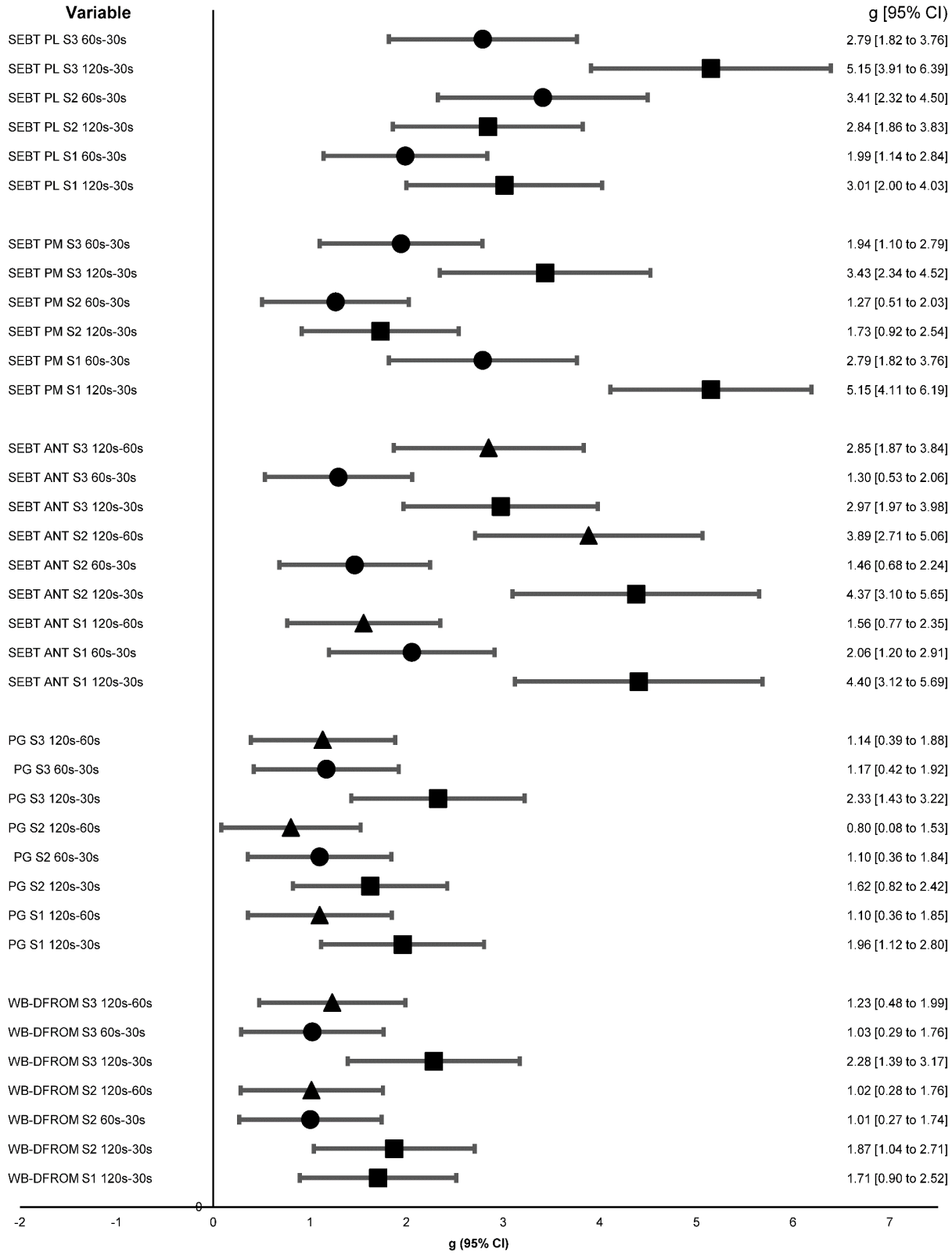

Figure 3. Forest plot ($g \pm 95\%$ CI) between treatment groups for weight-bearing dorsiflexion range of motion (WB-DFROM), posterior drawer (PG), and anterior (ANT), posteromedial (PM) and posterolateral (PL) directions of the Star Excursion Balance Test (SEBT) across three testing sessions for all statistically significant results.

For WB-DFROM all treatment durations produced significant improvements compared to their control ($p \leq 0.001$), with the exception of the 30 second treatment group following session 2 ($p \geq 0.05$). Effect sizes were ‘huge’ for the 120 second group following all sessions, session 2 and 3 for the 60 second group, and session 1 and 3 for the 30 second group. All other effect sizes were ‘very large’. Improvements were significantly greater in the 120 second treatment group than the 30 second group for all sessions ($p \leq 0.001$), and the 60 second group for session 2 and 3 ($p \leq 0.001$). The 60 second group showed improvement over the 30 second group for sessions 2 and 3 ($p \leq 0.001$).

PG for all treatment durations produced significant improvements compared to their control ($p \leq 0.001$), with the exception of the 30 second treatment group following session 2 ($p \geq 0.05$). Effect sizes were ‘huge’ for the 120 second group following all sessions, session 2 and 3 for the 60 second group, and session 1 for the 30 second group. All other effect sizes were ‘very large’. Improvements in PG were significantly greater in the 120 second group than the 60 second and 30 second group following all sessions ($p \leq 0.001$). The 60 second group showed improvement over the 30 second group for sessions 2 and 3 ($p \leq 0.001$).

For the anterior reach direction each group showed a significant improvement ($p \leq 0.001$) when compared to their control for all treatment sessions. Improvements were significantly greater for longer treatment durations compared to shorter ones for all sessions ($p \leq 0.001$) with all effect sizes being ‘huge’.

The posteromedial direction only showed improvements when compared to their control following session 1 for the 60 second group ($p \leq 0.05$). Improvements were significantly greater for both the 120 second and 60 second group compared to the 30 second group for all sessions ($p \leq 0.005$). Effect sizes for session 1 were 'small', 'large' and 'moderate' for the 30, 60, and 120 second treatment groups respectively. For session 2, treatment group effect sizes were negatively 'moderate' (30 second), 'very large' (60 second) and 'small' (120 second). For session 3 these were negatively 'moderate' (30 second), 'small' (60 second) and 'very large' (120 second).

The posteromedial direction only showed improvements when compared to their control following session 1 for the 30 second group ($p \leq 0.01$). Improvements were significantly greater for both the 120 second and 60 second group compared to the 30 second group for all sessions ($p \leq 0.005$). Effect sizes for session 1 were 'very large', 'moderate' and 'large' for the 30, 60, and 120s second treatment groups respectively. For session 2, treatment group effects sizes were 'negligible' (30 second), 'very large' (60 second) and negatively 'negligible' (120 second). For session 3 these were 'moderate' (30 second), 'small' (60 second), and 'moderate' (120 second).

DISCUSSION

Results showed that all treatment durations produced statistically significant improvements in WB-DFROM, posterior glide, and reach directions of the SEBT ($p < 0.001$). Accessory mobilisations are therefore an effective treatment for inducing acute changes in ankle motion and dynamic postural control in those with CAI and should be considered during their treatment regimen. Furthermore, our research suggests that the magnitude of change is influenced by treatment duration. The mechanical

outcome measures demonstrate that longer treatment durations confer greater improvements compared to shorter durations. Grade IV mobilisations work at the end of the available range producing a microfailure of the connective tissue restricting motion [40]. Connective tissue accommodates stress in a manner described by Hooke's law and the stress-strain curve, where a proportional relationship exists between the deformation of an elastic structure and the stress applied to it. During a grade IV mobilisation the tissue moves beyond its elastic limit to the yield point and into the plastic range [26]. This results in a permanent elongation of the tissue due to a failure of the collagen's force-relaxation response when a load is applied, or when the creep response causes deformation to occur too rapidly [26]. This deformation can occur from accumulated stress, potentially explaining the observed increase in ROM improvements as longer treatment durations are applied.

In a study by Green et al [13] on acute ankle sprains, improvements in DFROM were shown with an effect size of 0.45, 0.19 and 0.11 respectively for sessions 1, 2 and 3 [42]. Within the present study effect sizes for all treatment durations were of a 'very large' magnitude (≥1.20). This may be due to the chronic nature of the participants symptoms in our study or differences in the mobilisation intervention. Whilst Green et al [13] did not provide a definitive identification of the grade utilised, due to pain presence the intervention was a small-amplitude oscillation applied at the beginning of range. This would be defined as a grade I mobilisation which is used to reduce pain and not influence ROM. Comparisons with multiple studies by Hoch et al [22,24] highlight the benefit of using grade IV mobilisations over lower grades when improvements in arthrokinematic motion are being sought. In both studies, participants received 4, 2 minute sets of Maitland grade III mobilisations and 2, 2 minute sets of grade II joint

tractions for 6 treatment session over 2 weeks. In the earlier study, improvements in WB-DFROM were 12.4% with effect sizes of >3.0. Cumulatively over the 3 treatment session within the current study, all improvements were above this value (30s = 15.8%, 60s = 26.7%, 120s = 43.6%), with the 120 second group showing superior increases after each individual session. Effect sizes also showed very large (≥1.20) to huge (≥2.0) improvements following each treatment session for each group. With the latter Hoch et al study [22], a non-significant decrease of 0.88% was observed and effect size of -0.51 for posterior talar displacement. Significant improvements in PG were seen in the current study again with very large to huge effect sizes. Whilst grade III and IV mobilisations can work at the end of the available arthrokinematic range, grade IV mobilisations produce a far greater oscillatory frequency and mean force [40]. Greater loads are thus experienced by the connective tissue resulting in greater plastic deformation of the restrictive structures, explaining the greater improvements within the current study.

Only one study has attempted to ascertain the effects of increased mobilisation treatment durations on ankle range of motion. The methodologically similar study by Holland et al [25] identified that asymptomatic individuals elicited a greater improvement in WB-DFROM following a single treatment session as the duration of mobilisation increased. This was of the magnitude of 10.9% (120 second group), 7.6% (60 second group) and 5.0% (30 second group), although the authors concluded that none of these were above the minimal detectable change score. The differences between treatment durations were slightly greater in the current study when mean scores were calculated across each of the three treatment sessions (14.5%, 8.9% and 5.3% respectively). The greater improvement identified can be attributed to the use of

symptomatic CAI sufferers, many of whom demonstrated significant reductions in DFROM prior to the commencement of the intervention. At least 10^0 of DFROM is needed to walk, descend stairs or kneel [12], whilst running requires at least 20^0 [47]. CAI suffers often have DFROMs below 0^0 [41] due to the propensity of the talus towards anterior subluxation following a LAS resulting in restrictions in posterior noncontractile tissue and anterior ligament laxity [22]. This allows for greater changes in ROM to be elicited through the application of anterior-to-posterior joint mobilisations within this population.

Development in the anterior reach direction of the SEBT were significant for all treatment durations, with longer treatments again conferring greater improvements. These improvements can be attributed to their relationship to WB-DFROM, with research indicating that an estimated 28% of the variance in anterior reach distance can be attributed to this measure [23]. Following similar mobilisation treatments, Hoch et al [24] identified a significant improvement of 2.8% in anterior reach distance on the SEBT following 6 treatment sessions. The current study identified cumulative improvements beyond this value for all treatment groups (30s = 4.6%, 60s = 6.7%, 120s = 10.3%), whilst the 60 second treatment group demonstrating comparable values and the 120 second treatment group again showing superior values after each session individually. The effect sizes also identified these to be ‘huge’ for all groups across the three sessions. It is again postulated that these enhanced scores are related to the use of grade IV mobilisation and their ability to provide greater deformation of the connective tissue. However, much of the kinematic predictors of performance on the SEBT can be attributed to proximal joint motion, with hip and knee flexion accounting for 78% of the variance in maximal reach distance [36]. As such,

improvements in this measure will always be limited if only ankle joint mobility is being improved.

Whilst there were no real notable improvements for posterolateral or posteromedial reach distances when treatment groups were compared against controls, a statistically significant differences for all groups following all three sessions was revealed. Effect size calculations showed a full range of scores from negligible to very large, although no real pattern emerged. It is postulated that mobilisations may be having a bilateral effect on dynamic balance. Motor activity intervention of one limb has been shown to enhance performance within the contralateral untrained limb [38]. This 'cross-education' is thought to occur through neural mechanisms, with Carroll et al [5] suggesting two plausible mechanisms. First, unilateral treatment could cause a spill-over effect of neural drive from the active to the inactive hemisphere that induces adaptations in the control system of the contralateral limb. Second, treatment could cause 'bilateral access' in which neuromuscular adaptations in the control system of the treated limb become accessible by the opposite limb. This requires further investigation and is beyond the scope of the current study, as it must also be noted that contralateral effects could also be biased by familiarisation with the testing procedures, although this bias does appear small [5].

The potential limitations of the current study are that only a female collegiate age cohort was used. This may have limit the ability of the current study to generalise the results to wider populations as connective tissue exhibits changes in biomechanical properties and cross-sectional are in response to exercise, disuse and aging [44]. Studies have also shown that the tolerance of female ankle ligaments is significantly

less than that of males even in the absence of any previous ligamentous injury [39]. Another limitation of the study is that the long-term effects of the treatment was not assessed meaning that conclusions regarding the maintenance of the observed improvements cannot be made. In addition, treatment durations were limited to a maximum of 120 seconds and as such there can be no identification of whether improvements in outcome measures continue to increase through even longer durations or whether a ceiling effect occurs once given treatment duration is achieved.

CONCLUSION

The current study adds clarity to the use of joint mobilisations treatment and will add to the current clinical practice and rehabilitative strategies for those with CAI. These findings show that higher treatment durations confer greater improvements in arthrokinematic function and increased anterior reach distance in those with CAI with 120 second treatment durations being optimal when single sets are being applied within the first week of treatment. Further research is required to ascertain the period for which the observed differences are maintained, as well as investigating the use of multiple sets.

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