Chronic ankle instability in females: effectiveness of home-based exercises following joint mobilisation

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RESEARCH

Chronic ankle instability in females: effectiveness of home-based exercises following joint mobilisation

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Abstract

Purpose Ankle sprains are the most common musculoskeletal disorder, with up to 70% developing CAI, linked to mechanical and functional insufficiencies such as reduced DFROM and disrupted afferent transmission. Joint mobilisations improve DFROM, increase afferent input, enhance dynamic balance, and self-reported function in those with ankle sprains. However, research on the combined effect of mobilisation and home-based exercises is limited. The study determines if home-based rehabilitation can enhance functional improvements in WB-DFROM and dynamic postural control, following Grade IV anterior-to-posterior ankle joint mobilisation in females with CAI.

Methods The study adopted a randomised comparative intervention design. Forty-eight female athletes (age 22.5 ± 3.5 years) with unilateral CAI were randomly assigned to intervention or control groups. All participants received three 120-s Grade IV anterior-to-posterior talar joint mobilisation sessions, 48 h apart. The intervention group then completed 4 weeks of home-based rehabilitation exercises, with the control group maintaining normal activities. WB-DFROM and SEBT (ANT, PM, PL) were measured bilaterally before the first session, after the third, and weekly during rehabilitation. The uninjured limb served as a control. Data were analysed using mixed model ANOVAs and effect sizes with Hedge's g.

Results Significant differences were found after initial mobilisation in both groups ($p \leq 0.001$) with 'huge' effect sizes. The intervention group showed significant improvements in WB-DFROM, PM, and PL across all 4 weeks, and in ANT for weeks 1, 2, and 3.

Conclusion Joint mobilisation followed by home-based rehabilitation effectively treats CAI in females. An effective protocol includes three 120-s joint mobilisations in the first week, followed by 2 weeks of daily exercises targeting self-mobilisation and dynamic postural control.

Keywords Chronic ankle instability · Female · Mobilisation · Maitland · Manual therapy · Rehabilitation

Introduction

Chronic ankle instability (CAI) affects up to 76% of those with lateral ankle sprains, leading to recurrent instability, additional sprains, and reduced functional capacity, which can limit physical activity and daily living for years and decrease health-related quality of life [1]. Conservative management is the primary approach, with early and effective initial treatment yielding the most favourable results [2]. Clinical guidelines recommend manual therapy (including joint mobilisations) and therapeutic exercises to rehabilitate ankle stability and movement coordination impairments [3–5]. Previous work [5] shows that talocrural joint mobilisation can acutely improve dorsiflexion range of motion (DFROM) and aspects of dynamic balance, while home-based exercise can be feasible and cost effective when adherence is adequate [6, 7]. Nevertheless, much of the literature evaluates these approaches in isolation, leaving uncertainty about how best to sequence brief clinician-delivered mobilisation with a pragmatic home-based programme that patients can perform independently. Research that reflects real-world constraints and the combination and sequencing of therapeutic interventions

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it therefore needed. The study focused on female athletes to address a cohort underrepresented in parts of the literature and to ensure a homogeneous sample. While the study was not designed to test sex-specific mechanisms, concentrating on females improves internal consistency and recognises pragmatic considerations around access to care and self-management. Generalisation to mixed sex cohorts should therefore be made cautiously. The primary objective of the study was to determine whether adding a home-based programme maintains or augments mobilisation-related gains in weight-bearing (WB) DFROM and dynamic postural control in female athletes with CAI. It was hypothesised that joint mobilisations will result in improvement in DFROM and dynamic postural control, and the application of home-based exercise will augment these improvements further.

Methods

Participants

A randomised single-blind clinical trial included 68 female collegiate athletes with self-reported CAI, with 48 completing the study (mean age 22.5 ± 3.5 years; height 169.4 ± 7.3 cm; mass 69.7 ± 6.3 kg). The sample size was calculated in G*Power 3.1.9 [8] using partial eta-squared effect sizes derived from the authors' previous work [5], with power set at 95% and alpha at 0.05, indicating the required sample of 48. Inclusion and exclusion criteria followed the International Ankle Consortium's standards [9], requiring a history of at least one ankle sprain in the last 12 months and a CAIT score below 24. Participants with recent surgery, fractures, or acute injuries were excluded. The study adhered to the Helsinki Declaration and received ethical approval. All participants provided written consent and were screened for contraindications to mobilisation.

Participants were randomly assigned to the intervention or control group (Fig. 1). Participants and researchers were blinded to group allocation until the joint mobilisation treatments had been completed. Baseline limb lengths were measured bilaterally to calculate normalised star excursion balance test (SEBT) reach distances. WB-DFROM and dynamic postural control were measured for both limbs using established protocols [10] at baseline, post-mobilisation, and weekly for 4 weeks. The study was structured intentionally so that all participants received three 120-s Grade IV anterior-to-posterior talar joint mobilisation sessions, 48 h apart. After the third session, participants were instructed based on their group assignment. The intervention group received home-based rehabilitation exercises to be completed daily for 4 weeks. Exercises were demonstrated and observed to ensure correct performance. The control group maintained normal activities without specific ankle exercises. Follow-up testing occurred at 7, 14, 21, and 28 days post-intervention. Adherence to the rehabilitation programme was verbally confirmed at each session, and non-adherent participants were removed from the study.

Dorsiflexion range of motion

WB-DFROM was measured using the knee-to-wall principle [10]. Participants stood facing a wall with the second toe and heel perpendicular to it, performing a lunge to touch the knee to the wall while keeping the heel on the floor. The foot was moved back in 1 cm increments until knee and heel contact could not be maintained; then smaller increments were used. The maximum distance from the wall to the great toe was measured. Movements were monitored to ensure they occurred in the sagittal plane. This method provides a greater DFROM measurement than other positions and has excellent reliability (ICC 0.94) [11].

Star excursion balance test (SEBT)

Dynamic postural control was assessed using the anterior, posterior, and posterolateral directions of the SEBT (Fig. 2). The test foot was positioned in each quadrant of the SEBT and marked for accurate repositioning [12]. Participants performed maximal reaches with the uninvolved limb slightly touching the tape measure. Trials were discarded if the hands did not remain on hips, stance foot or heel contact was lost, or balance was compromised. Distances were measured in centimetres and normalised to leg length [13]. The average of three trials was used, with each direction examined independently. This method is highly reliable (ICC 0.83–0.96) [12].

Joint mobilisation intervention

Joint mobilisation was performed with participants supine, foot over the end of the plinth, and ankle at 20° plantar flexion to achieve the talocrural loose-packed position. The stabilising hand was placed proximal to the malleoli, and the mobilising hand cupped the anterior talus. The talus was glided posteriorly with downward force [14] (Fig. 3). The mobilisation was a Grade IV, 1-s rhythmic oscillation to tissue resistance, with constant oscillation speed maintained using a metronome. This technique mimics functional loading and unloading of tissue.

Ankle self-mobilisation

Participants performed the self-mobilisation technique daily, following a standardised procedure [15]. While lunging, the participant elevated the injured foot on a 20 cm step and used

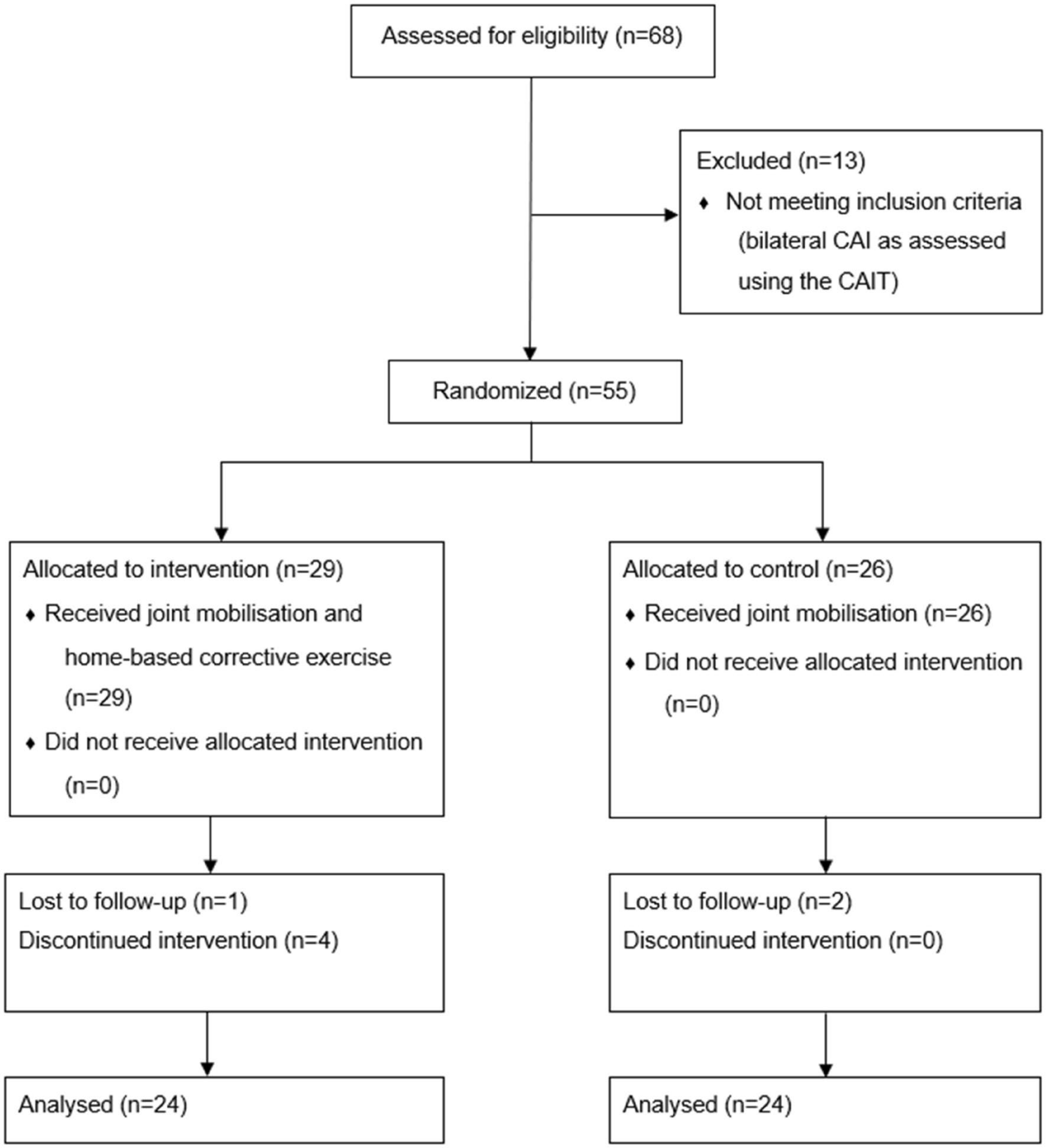

Fig. 1 Flow diagram of participants. *CAI* chronic ankle instability, *CAIT* Cumberland Ankle Instability tool

a 40 cm nonelastic strap. A narrow strap was intentionally used to allow precise posterior translation of the talus, mirroring the small contact area applied by a practitioner during Maitland anterior-to-posterior mobilisations. The step height was chosen to replicate a standard stair riser, thereby ensuring participants performed the home-based exercise using a consistent and functionally representative step height. The injured ankle was placed on the step, with the uninjured foot on the ground in a lunge position. The strap was placed around the anterior talus, just below the malleoli, and the medial rear foot on the ground (Fig. 4). The step controlled the strap's angle to mimic therapist-applied joint mobilisation. Participants pulled the strap taut and moved the injured knee forward in a lunge, applying anteroposterior force to the talus. The end position was when the heel could no longer maintain contact with the step, held for 20 s before returning to the initial position. This was repeated 15 times, with 10-s rest between repetitions.

Rehabilitation intervention

Participants completed the anterior, posteromedial, and posterolateral directions of the SEBT. They received instructions detailing the SEBT directions and exercise

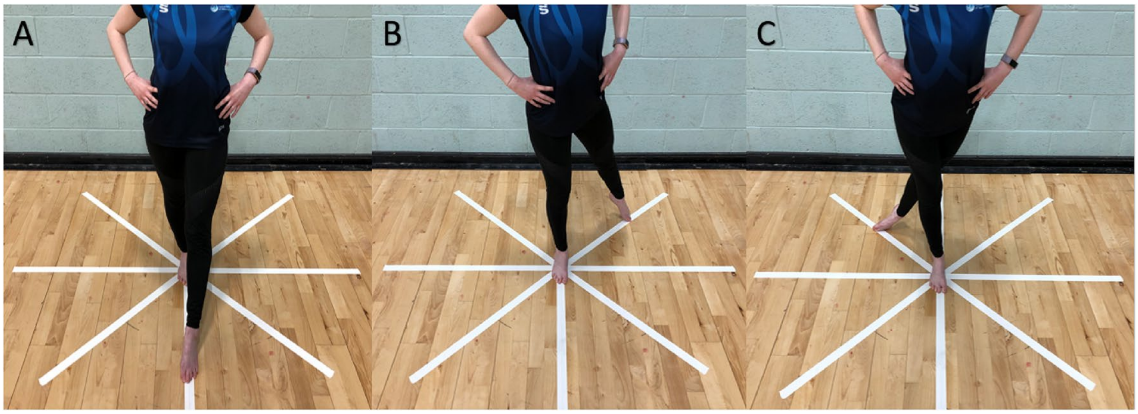

Fig. 2 Star excursion balance test directions and foot placement. Directions are described in relation to anatomical position. **A** Anterior, **B** posterolateral, **C** posteromedial

Fig. 3 Grade IV anterior-to-posterior talar joint mobilisation

Fig. 4 Ankle self-mobilisation using a strap

protocol (Fig. 2), ensuring correct foot alignment without needing to set up a full SEBT each time. The injured limb was positioned with equal halves of the foot in each SEBT quadrant. Participants performed maximal reaches in the three directions with the uninvolved limb, followed by a light toe touch on the tape measure. They completed 15 repetitions in each direction. Repetitions were not counted if hands did not remain on hips, stance foot position was not maintained, the heel lost contact with the floor, or balance was lost.

Statistical analysis

Percentage improvement for each dependent variable was calculated within each testing session for clinical relevance. Mixed model ANOVAs ($p \leq 0.05$) examined differences in dependent variables separately. Independent variables were time (pre–post mobilisation, week 1, 2, 3, 4), group (intervention, control), and limb (injured, uninjured). Post hoc comparisons used Tukey's HSD for group effects. Effect sizes (ES) were calculated between injured limb and control, and groups using 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) [16].

Table 1 Percentage change and standard deviation for *WBLT* weight-bearing lunge test, *Ant* anterior, *PM* posteromedial and *PL* posterolateral directions of the star excursion balance test (*SEBT*) across the 5-day joint mobilisation intervention prior to the home-based rehabilitation intervention

Variables	Intervention group			
	Intervention		Control	
	Injured	Uninjured	Injured	Uninjured
WBLT	**46.27 ± 8.11**	0.17 ± 0.83	**43.98 ± 5.09**	0.14 ± 0.85
SEBT-Ant	**12.81 ± 4.09**	0.05 ± 0.30	**12.04 ± 3.02**	−0.07 ± 0.40
SEBT-PL	**8.48 ± 2.32**	0.02 ± 0.49	**8.81 ± 2.10**	0.05 ± 0.45
SEBT-PM	**7.43 ± 2.46**	0.24 ± 0.36	**7.99 ± 2.56**	0.27 ± 0.45

Bold font indicates significance when compared to the uninjured limb

Results

Mobilisation intervention

Mean ± standard deviation for each measure is presented in Table 1. There were significant improvements in the intervention and control group ankles receiving mobilisation compared to the uninjured one (WBLT, ANT, PL, PM = $p \leq 0.001$), with no significant difference between the intervention and control groups that received mobilisation ($p \geq 0.05$), or the uninjured ankles that did not ($p \geq 0.05$). ES statistics indicated a 'huge' effect ($g \geq 2.00$) for both groups receiving mobilisation.

Rehabilitation intervention

Mean ± standard deviation for each measure is presented in Table 2. In week 1 the intervention group showed significant improvements in the injured ankle for WBLT (18.06%), ANT, and PM ($p \leq 0.001$), but not PL ($p \geq 0.05$). The control group improved in WBLT and ANT ($p \leq 0.001$), with no significant changes in PL or PM. Between-group differences

Table 2 Percentage change and standard deviation for the *WBLT* weight-bearing lunge test, *ANT* anterior reach distance, *PL* posterolateral reach distance and *PM* posteromedial reach distance for intervention and control groups across the 4-week home-based exercise programme

Variables	Time	Intervention group			
		Intervention		Control	
		Injured	Uninjured	Injured	Uninjured
WBLT	Week 1 (post-mobilisation to week 1)	**18.06 ± 5.90[b]**	0.01 ± 1.01	**−10.39 ± 1.84[a]**	−0.20 ± 0.71
	Week 2 (week 1 to week 2)	**9.04 ± 3.13[b]**	0.02 ± 0.77	**−3.55 ± 1.46[a]**	0.02 ± 0.66
	Week 3 (week 2 to week 3)	**3.65 ± 1.63[b]**	0.14 ± 0.62	−0.14 ± 1.70[a]	−0.08 ± 0.61
	Week 4 (week 3 to week 4)	**2.75 ± 1.80[b]**	0.04 ± 0.76	−0.71 ± 1.73[a]	0.10 ± 0.52
	Post-mobilisation to week 4	**37.24 ± 10.78[b]**	0.19 ± 0.90	**−14.31 ± 2.65[a]**	−0.16 ± 0.83
ANT	Week 1 (post-mobilisation to week 1)	**6.38 ± 2.08[b]**	−0.01 ± 0.34	**−6.06 ± 1.74[a]**	−0.01 ± 0.15
	Week 2 (week 1 to week 2)	**3.50 ± 1.30[b]**	0.02 ± 0.27	−0.01 ± 0.21[a]	0.03 ± 0.13
	Week 3 (week 2 to week 3)	**2.99 ± 0.93[b]**	0.06 ± 0.26	0.11 ± 0.54[a]	0.00 ± 0.17
	Week 4 (week 3 to week 4)	**0.70 ± 0.85**	−0.38 ± 1.82	0.75 ± 1.41	−0.04 ± 0.21
	Pre-mobilisation to week 4	**14.21 ± 4.06[b]**	−0.32 ± 1.84	**−5.96 ± 1.76[a]**	0.02 ± 0.22
PL	Week 1 (post-mobilisation to week 1)	1.32 ± 1.03[b]	0.51 ± 0.47	−0.51 ± 2.00[a]	−0.00 ± 0.09
	Week 2 (week 1 to week 2)	**3.71 ± 2.42[b]**	0.66 ± 0.52	0.10 ± 0.33[a]	0.01 ± 0.11
	Week 3 (week 2 to week 3)	**5.20 ± 2.22[b]**	1.13 ± 0.85	−0.05 ± 0.85[a]	−0.10 ± 0.50
	Week 4 (week 3 to week 4)	**1.45 ± 0.97[b]**	0.58 ± 0.40	0.01 ± 0.86[a]	0.04 ± 0.51
	Pre-intervention to week 4	**12.19 ± 5.29[b]**	2.91 ± 1.38	−0.47 ± 1.90[a]	−0.06 ± 0.38
PM	Week 1 (post-mobilisation to week 1)	**5.61 ± 1.70[b]**	0.25 ± 0.39	−0.18 ± 0.93[a]	−0.06 ± 0.11
	Week 2 (week 1 to week 2)	**4.70 ± 1.70[b]**	0.61 ± 0.39	−0.33 ± 0.68[a]	−0.10 ± 0.16
	Week 3 (week 2 to week 3)	1.58 ± 0.69[b]	1.64 ± 1.03	−0.10 ± 0.51[a]	0.08 ± 0.24
	Week 4 (week 3 to week 4)	0.86 ± 0.57[b]	0.53 ± 0.47	0.13 ± 0.44[a]	0.07 ± 0.37
	Pre-intervention to week 4	**13.31 ± 4.36[b]**	3.06 ± 1.36	−0.47 ± 1.85[a]	−0.02 ± 0.28

[a]Significant compared to the injured intervention group

[b]Significant compared to the injured control group; bold font indicates significance when compared to the uninjured limb

were significant for WBLT, ANT, PL, and PM ($p \leq 0.001$), but not for uninjured limbs. Effect sizes were huge ($g \geq 2.00$) in the intervention group and huge negative ($g \geq -2.00$) for WBLT and ANT in the control group, with small negative ES for PL and PM. In week 2, the intervention group showed significant improvements in WBLT (9.04%), ANT, PL, and PM ($p \leq 0.001$). The control group improved in WBLT and PM ($p \leq 0.001$), but not ANT or PL. Between-group differences were significant for all variables ($p \leq 0.001$), except PM ($p \leq 0.05$). Effect sizes remained huge ($g \geq 2.00$) in the intervention group and negative in the control group, with the largest contrast in WBLT. In week 3 the intervention group improved in WBLT (3.75%), ANT, and PL ($p \leq 0.001$), but not PM. The control group showed gains in WBLT and ANT ($p \leq 0.001$), with no change in PL or PM. Between-group differences were significant for PL and PM ($p \leq 0.001$), but not WBLT or ANT. Effect sizes were huge ($g \geq 2.00$) in the intervention group and negligible to small negative in the control group. In week 4 the intervention group showed improvements in WBLT (2.75%), ANT, and PL ($p \leq 0.001$), but not PM. The control group showed no significant changes ($p \geq 0.05$). Between-group differences were significant for WBLT, PL, and PM ($p \leq 0.001$), but not ANT ($p \leq 0.05$). Effect sizes were very large for WBLT ($g \geq 1.20$), large for PL ($g \geq 0.80$), and moderate for ANT and PM ($g \geq 0.50$) in the intervention group. In the control group, ES were moderate negative for WBLT ($g \geq -0.50$), moderate for ANT ($g \geq 0.50$), and negligible for PL and PM.

Discussion

The observed improvements in outcome measures following the joint mobilisation intervention demonstrate that this can significantly improve arthrokinematic motion and dynamic postural control, with comparable changes to those observed in previous studies [5, 17]. The significant effects elicited in the injured limb for both intervention and control groups shows that three sessions of 120 s of Grade IV anterior-to-posterior talar joint mobilisations is an effective means to improve function in those with CAI prior to commencing a home-based rehabilitation programme.

The study further indicates that while significant improvements in arthrokinematic function can be achieved through a home-based exercise regime preceded by joint mobilisation, these are short-term gains not sustained in the absence of continued rehabilitation. This highlights the importance of ongoing intervention to maintain functional improvements, which were modestly improved within the current study. Across the 4-week testing period, improvements in dorsiflexion range of motion (DFROM) were observed in all groups; however, the injured intervention group demonstrated superior gains compared to the uninjured control limb, whereas the injured control group exhibited a decline in function during the initial two weeks. Specifically, the intervention group achieved an 18.06% improvement in week 1, although this benefit diminished progressively over the subsequent weeks (9.04, 3.75, and 2.75%). These findings underscore the necessity of progressive exercise prescription to sustain adaptation, as the effectiveness of the home-based programme appeared to plateau. This is consistent with the work of Jeon et al. [15], who reported a 13.5% improvement in weight-bearing lunge test (WBLT) using a similar self-mobilisation technique.

In the present study, cumulative improvements in WBLT reached 37.24%, with the majority occurring within the first two weeks, suggesting that restored talar motion may underpin these gains. However, imaging techniques would be required to confirm resolution of the anterior positional fault. The improvements observed are likely attributable to enhanced accessory joint movement and stretching of the triceps surae complex, which plays a critical role in dorsiflexion. The self-mobilisation protocol involved a weight-bearing lunge with the test foot elevated, facilitating gastrocnemius and soleus stretching. Repeated stretching may increase DFROM by altering the muscle–tendon unit and myotendinous junction. The use of a mobilisation strap induced a posterior talar glide, contributing to the restoration of normal ankle mechanics. Previous research [18] supports the combined use of talar mobilisation and gastrocnemius stretching as more effective than stretching alone. Interestingly, the control group demonstrated significant reductions in WBLT in the injured limb during the first two weeks of the home-based intervention indicating that some improvements are attenuated after treatment cessation. This may be explained by viscoelastic tissue behaviour, where elastic recoil and non-permanent creep deformation result in a return to pre-intervention tissue length [19]. Despite this transient decline, the initial mobilisation intervention still produced improvements beyond baseline, reinforcing its value as a preparatory phase for rehabilitation.

The study demonstrates that home-based rehabilitation exercises can maintain and enhance dynamic postural control in individuals with CAI. Improvements in SEBT reach distances (ANT, PL, PM) varied in timing and magnitude. The anterior reach showed consistent gains across all 4 weeks in the injured intervention group, with diminishing returns likely due to a ceiling effect. ANT improvements corresponded to WBLT performance, accounting for 35.3% (week 1), 38.7% (week 2), 81.9% (week 3), and 25.5% (week 4) of WBLT gains. PL reach improved significantly in weeks 2–4, peaking in week 3, while PM reach improved only in weeks 1 and 2, peaking in week 1. These changes reflect sensorimotor system plasticity, with rapid neural adaptations and delayed structural responses, but are likely a combination of neuromuscular adaptation and task familiarity.

Differences in movement mechanics and muscle activation between PL and PM also influenced timing; PL requires less knee flexion and greater gluteus maximus activation, which is often delayed in individuals with CAI.

Comparisons with existing literature are limited, though Mckeon et al. [20] reported 10.98% and 12.99% improvements in PM and PL, respectively, after a 4-week supervised balance programme, with no change in ANT. In contrast, this study found improvements of 13.31% (PM), 12.19% (PL), and 14.21% (ANT). These differences may be due to training frequency, which was daily in this study versus three times per week in McKeon's, and the specificity of exercises, which in McKeon's protocol did not directly target DFROM, a key factor in ANT performance.

The study relied on participants' adherence to the home-based rehabilitation program, confirmed verbally before each testing session. Although all participants reported full compliance, self-reported adherence can be unreliable, with rates of non-adherence reaching up to 50% [21]. Given the athletic background and demographic (younger females), and the brief nature of the programme (12 min daily), adherence was likely accurate. The absence of financial incentives further reduces the risk of over-reporting, which is more common in older male participants seeking trial compensation [22, 23]. Future studies should incorporate objective adherence measures, such as electronic tracking or supervised sessions. The repeated use of the SEBT as both an assessment and intervention tool may have introduced the potential for a learning effect that may inflate reach distances independent of sensorimotor adaptations. Furthermore, balance training often leads to task-specific adaptations with limited transferability [24, 25]. Future iterations should include an additional balance outcome not used in training to strengthen causal inference. Although reach distance was progressively increased, the intervention lacked broader progression, possibly contributing to a ceiling effect. Effective rehabilitation requires tailored progression based on clinical reasoning. This study highlights when progression may be necessary for individuals with CAI, and future research should aim to define performance thresholds to guide progression without clinician oversight. Although effect sizes were included to quantify the magnitude of change beyond statistical significance, their interpretation should consider methodological influences such as percentage-based change scores, limb-to-limb comparisons, and repeated testing. Nonetheless, effect sizes remain clinically meaningful in this context, helping illustrate the consistency and practical relevance of the improvements observed. Finally, while focusing on females improved sample homogeneity and pragmatic relevance, the trial was not designed to test sex specific mechanisms; therefore, generalisation beyond female athletes should be cautious until comparable data are available in mixed sex cohorts.

Conclusions

In female athletes with CAI, three sessions of high-grade talocrural mobilisation produced substantial immediate improvements in DFROM and dynamic balance measures. A brief, daily home-based programme appeared to preserve and modestly extend these gains over the subsequent 4 weeks, whereas gains tended to attenuate without continued rehabilitation. Combining joint mobilisation and home-based rehabilitation can be an effective part of the initial intervention for CAI. An applicable protocol includes three 120-s high-grade joint mobilisations in the first week, followed by 2 weeks of daily rehabilitation exercises focusing on task-specific ankle self-mobilisation and dynamic postural control.

Author contributions Christopher Holland (CH) led the study design, data collection, analysis, and manuscript preparation. JH and MDST provided critical review, amendments, and guidance throughout the research process and manuscript development. All authors approved the final version of the manuscript.

Data availability No datasets were generated or analysed during the current study.

Declarations

Conflict of interest The authors declare no competing interests.

Ethical approval The research was approved by the University of Gloucestershire's Research Ethics Committee. REC Approval Code: REC.18.64.2.2.

Informed consent All participants provided written consent and were screened for contraindications to treatment.

Declaration of Helsinki The Declaration of Helsinki is the premier ethical guideline for medical research involving human subjects, fi rstadopted in 1964 by the World Medical Association (WMA). It mandates that the health, dignity, and privacy ofresearch participants take precedence over the interests of science or society. It has been updated consistenctlysince 1964 with the most major update being in 2024.

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