

# Ankle-Joint Self-Mobilization and CrossFit Training in Patients With Chronic Ankle Instability: A Randomized Controlled Trial

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**Context:** Ankle-joint mobilization and neuromuscular and strength training have been deemed beneficial in the management of patients with chronic ankle instability (CAI). CrossFit training is a sport modality that involves these techniques.

**Objective:** To determine and compare the influence of adding self-mobilization of the ankle joint to CrossFit training versus CrossFit alone or no intervention in patients with CAI.

**Design:** Randomized controlled clinical trial.

**Setting:** Research laboratory.

**Patients or Other Participants:** Seventy recreational athletes with CAI were randomly allocated to either self-mobilization plus CrossFit training, CrossFit training alone, or a control group.

**Intervention(s):** Participants in the self-mobilization plus CrossFit group and the CrossFit training-alone group pursued a CrossFit training program twice a week for 12 weeks. The self-mobilization plus CrossFit group performed an ankle self-mobilization protocol before their CrossFit training, and the control group received no intervention.

**Main Outcome Measure(s):** Ankle-dorsiflexion range of motion (DFROM), subjective feeling of instability, and dynamic postural control were assessed via the weight-bearing lunge test, Cumberland Ankle Instability Tool, and Star Excursion Balance Test (SEBT), respectively.

**Results:** After 12 weeks of the intervention, both the self-mobilization plus CrossFit and CrossFit training-alone groups improved compared with the control group ( $P < .001$ ). The self-mobilization plus CrossFit intervention was superior to the CrossFit training-alone intervention regarding ankle DFROM as well as the posterolateral- and posteromedial-reach distances of the SEBT but not for the anterior-reach distance of the SEBT or the Cumberland Ankle Instability Tool.

**Conclusions:** Ankle-joint self-mobilization and CrossFit training were effective in improving ankle DFROM, dynamic postural control and self-reported instability in patients with CAI.

**Key Words:** range of motion, balance, rehabilitation

## Key Points

- Among patients with chronic ankle instability, ankle-joint self-mobilization was effective in improving the self-reported instability, ankle-dorsiflexion range of motion, and dynamic postural control.
- CrossFit training alone also improved ankle-dorsiflexion range of motion, dynamic postural control, and self-reported instability.
- Adding self-mobilization to CrossFit training produced better results than either intervention alone.

Lateral ankle sprain is the most common sport-related injury. It has been reported<sup>1</sup> that up to 75% of those who have sustained this injury are susceptible to recurrent ankle sprains. Furthermore, an estimated 33% of patients with an ankle sprain will develop chronic ankle instability (CAI),<sup>2</sup> which is characterized by residual symptoms that include episodes of giving way, feelings of ankle-joint instability, chronic pain, recurrent sprains, and swelling.<sup>2</sup> Associated impairments such as a deficit in ankle-dorsiflexion range of motion (DFROM), altered arthrokinematics, and sensorimotor deficits may be present for decades in these patients, resulting in diminished health-related quality of life.<sup>2,3</sup>

Balance training has been widely described in the scientific literature as an effective intervention for patients with CAI.<sup>4</sup> In conjunction with the evolution of the CAI model in recent years, researchers<sup>5–7</sup> have also evaluated

strength training, joint mobility, and manual therapy in managing this condition; the results indicate a multifactorial approach is appropriate. Limited ankle DFROM has been associated with deficits in postural control and dynamic balance in those with CAI.<sup>8</sup> Investigators<sup>7,8</sup> have shown the benefits of joint mobilization in improving kinematics and dynamic balance as well as performance on functional tests. In addition to manual therapy, ankle-joint self-mobilization has been applied with positive results.<sup>9,10</sup> Nevertheless, little evidence is available about the effects of combining self-mobilization and neuromuscular training.

Despite the heterogeneity and complexity of CAI symptoms, neuromuscular-training research is usually characterized by single interventions (either strength or balance training).<sup>11</sup> CrossFit (CrossFit, Inc, Santa Cruz, CA) is a form of high-intensity training based on functional exercises that involve weightlifting, gymnastics, and

**Table 1. Participant Characteristics and Baseline Comparability of Study Groups**

Characteristic	All (n = 70)	Group			P Value <sup>a</sup>
		CrossFit Plus Self-Mobilization (n = 25)	CrossFit Alone (n = 24)	Control (n = 21)	
Sex		No. (%)			.298
Male	40 (57.1)	17 (68)	11 (45.8)	12 (57.1)	
Female	30 (42.9)	8 (32)	13 (54.2)	9 (42.9)	
Ankle		No. (%)			.497
Left	26 (37.1)	8 (32)	8 (33.3)	10 (47.6)	
Right	44 (62.9)	17 (68)	16 (66.7)	11 (52.4)	
		Mean ± SD			
Age, y	29.00 ± 8.50	29.16 ± 8.38	27.63 ± 7.42	30.38 ± 9.86	.558
Height, cm	170.97 ± 8.70	170.08 ± 8.02	171.71 ± 8.48	171.19 ± 9.99	.804
Mass, kg	69.25 ± 9.72	69.04 ± 10.35	69.03 ± 9.54	69.77 ± 9.62	.959
Body mass index	23.66 ± 2.62	23.76 ± 2.42	23.42 ± 2.92	23.81 ± 2.61	.863
Baseline scores					
Cumberland Ankle Instability Tool (range = 0–30)	18.91 ± 1.97	18.84 ± 2.08	18.92 ± 1.84	19.00 ± 2.07	.964
Ankle-dorsiflexion range of motion	8.81 ± 1.02	8.72 ± 1.19	8.97 ± 1.01	8.75 ± 0.83	.669
Star Excursion Balance Test Direction					
Anterior	75.47 ± 2.79	75.14 ± 2.42	76.40 ± 2.97	74.80 ± 2.84	.120
Posteromedial	89.64 ± 3.53	89.92 ± 3.05	89.70 ± 4.20	89.22 ± 3.37	.798
Posterolateral	87.19 ± 3.25	86.85 ± 2.41	86.93 ± 4.04	87.90 ± 3.15	.494

<sup>a</sup> P value for 1-way analysis-of-variance test for continuous variables or Kruskal-Wallis test for categorical variables.

metabolic workouts.<sup>12</sup> The literature on CrossFit training is limited, although the number of scientific publications has increased lately due to its growing popularity. Until recently, the most frequently studied topic involving CrossFit was the risk of injury.<sup>12–14</sup> However, this sport modality is based on improving strength, joint mobility, and balance, according to the specific features of the exercises performed. Although some authors have reported on core training, hip strengthening, ankle-joint stretching, and peroneal strengthening for improving ankle instability, only in the past few years have combinations of these training options been evaluated.<sup>15,16</sup>

Our hypothesis was that taking part in a CrossFit-based intervention that included self-mobilization techniques would improve DFROM, dynamic postural control, and self-reported instability of patients with CAI.

## METHODS

This study was a single-blinded randomized controlled trial with 2 intervention groups: 1 with an ankle-joint self-mobilization plus CrossFit protocol and the other with a CrossFit-based training protocol. Control-group participants received no intervention. Participants were assigned to 1 of the intervention conditions or the control group. The dependent variables were DFROM of the ankle joint assessed by the weight-bearing lunge test (WBLT), dynamic balance evaluated using the Star Excursion Balance Test (SEBT), and self-reported feeling of ankle instability determined by the Cumberland Ankle Instability Tool (CAIT). Participants were assessed before the study and after 12 weeks of intervention. The study (NCT03189784) was approved by the Human Ethics Committee of the University of Jaén and conducted in accordance with the

Declaration of Helsinki, good clinical practices, and applicable laws and regulations, and it met the standards of the Consolidated Standards of Reporting Trials guidelines.<sup>17</sup> Informed consent was obtained from all participants enrolled in the study.

## Participants

From a sample of 108 participants, 75 physically active participants with CAI were recruited by advertisement and word of mouth at the university's campus, physiotherapy centers, and hospitals. Participants were considered *physically active* if they exercised at least 2 times per week. We assessed participation eligibility using the recommendations of the International Ankle Consortium<sup>5</sup>: (1) a previous ankle sprain at least 6 months before the study, (2) a score of 25 or less on the CAIT to confirm current subjective ankle-joint instability, (3) no history of other musculoskeletal injuries in the lower limbs, and (4) mental and physical ability to participate in CrossFit sessions. Exclusion criteria for participants were (1) self-reported vestibular or balance-related dysfunction, (2) an acute ankle sprain in the previous 6 weeks, (3) recent surgery, or (4) being a habitual CrossFit practitioner. Participants' demographic information can be found in Table 1.

The sample size was calculated using Ene (version 3.0; GlaxoSmithKline, Barcelona, Spain) to ensure a power of 0.80 at a significance level of 95%, based on data from a study<sup>8</sup> of joint-mobilization interventions. A total of 21 participants per group were required. To compensate for possible dropouts during the intervention and assessment process, we recruited 25 patients per group. Participants' data were excluded from the statistical analysis if they missed more than 2 training sessions.

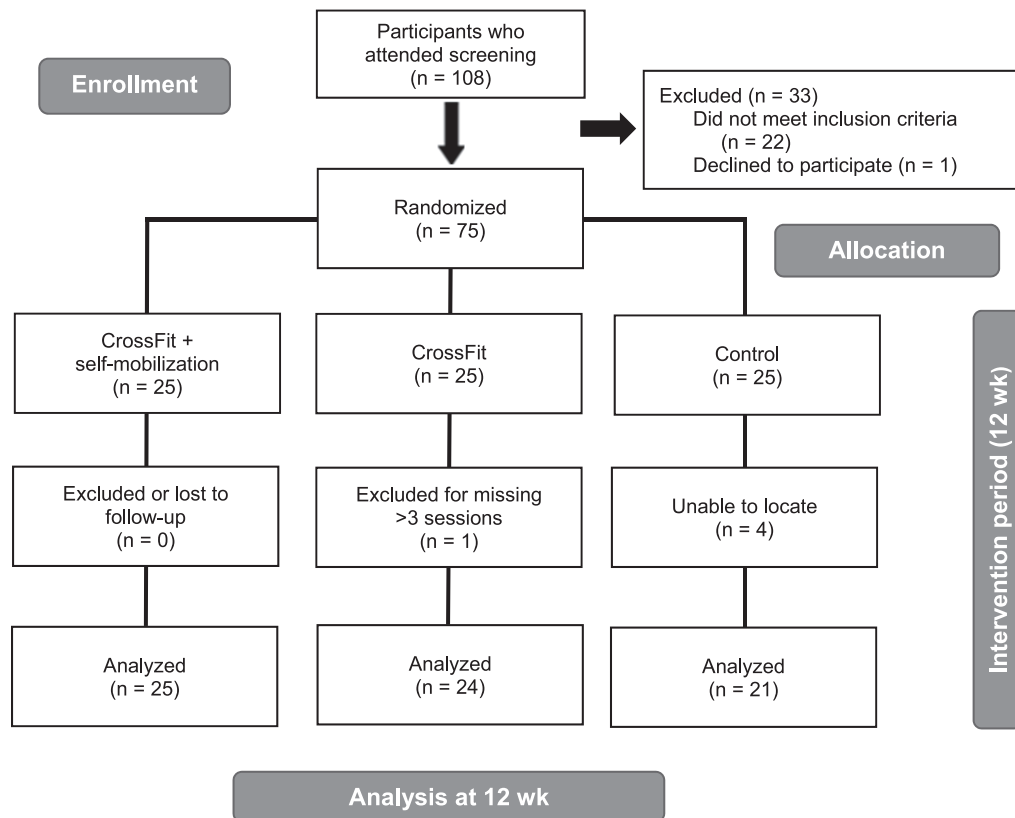


Figure 1. Flow chart of the study design and participant follow-up during the trial.

## Randomization

An independent assessor, blinded to data collection, was responsible for the allocation process. A list of computer-generated numbers was used to assign participants to the ankle-joint self-mobilization plus CrossFit group, the CrossFit training group, or the control group. Participants were randomized to each intervention group using sealed opaque envelopes prepared by an independent researcher (uninvolved in the intervention) in a 1 : 1 : 1 ratio before the intervention (Figure 1). Patients were instructed not to discuss the specifics of the intervention with the researchers.

## Interventions

Patients who met the inclusion criteria and agreed to enroll in the study were informed about the study protocol and advised to maintain their usual everyday activity. We provided a notebook to each participant to record any adverse event during the study. Dependent variables were measured by an independent assessor (a physiotherapist with more than 5 years of research experience) who was blinded to patient allocation.

**CrossFit Training.** The session was divided into 3 parts: a warm-up period, a principal training phase (which is known in CrossFit as the Workout of the Day [WOD]), and a cool-down aimed at easing recovery after the effort. The warm-up period consisted of cardiovascular activity, dynamic stretching, and progressive-load strength exercises. The main portion of the training session consisted of exercises to address strength, endurance, agility, and functional mobility. The difficulty level of each exercise

was controlled by a certified instructor who monitored the participant's form. Some exercises were based on body weight, such as a squat or burpees, whereas others required specific equipment such as barbells, kettlebells, or medicine balls. The final part of each session consisted of slow cardiovascular activity and foam rolling. The exercises are described in Table 2.

**Ankle-Joint Self-Mobilization and CrossFit.** This group carried out the same CrossFit protocol in addition to self-mobilization techniques at the beginning of the session and before the warm-up. This protocol was taught by an expert physical therapist who was also certified as a strength coach. The self-mobilization exercises were

- Ankle-joint self-mobilization with a resistance band. Participants placed a resistance band (Rogue Monster Band, Rogue Fitness HQ, Columbus, OH) around the talocrural joint with the affected foot on a step and the opposite leg extended in a lunge position. The band was tied posteriorly to a rack, and patients were told to perform ankle dorsiflexion while avoiding knee valgus.
- Kettlebell dorsiflexion. Participants adopted a kneeling-lunge position with the affected foot firmly placed on the ground. Then they performed maximal ankle dorsiflexion with a kettlebell placed on the bended knee of the anterior leg.
- Band pull. For this exercise, 2 bands were needed. Patients sat on the floor with the affected leg extended. One band was placed around the ankle joint and tied horizontally to a rack, exerting a caudal distraction force on the joint. A second band embraced the sole of the foot, and the patients were told to pull in a cranial direction.

**Table 2. CrossFit Training Protocol Continued on Next Page**

Training Session	Warm-Up	Workout of the Day	Repetitions and Sets or Time
1	Articular mobility Hinge PVC overhead squats Medicine ball slams Bear walk Hindu push-ups 50 Double-unders	Power cleans Burpees Box jumps	3 × 21/15/9 3 × 21/15/9 3 × 21/15/9
2	Articular mobility Hinge PVC overhead squats Medicine ball slams Bear walk Hindu push-ups 50-cal row	As many repetitions as possible 1. Push and press/chest dips 2. Battle rope/plank 3. Ball wall/chest to bar	10 min per station 10 × 10
3	Articular mobility Hinge PVC overhead squats Medicine ball slams Bear walk Hindu push-ups 50 air squats	3 rounds Clean and jerk Strict handstand push-ups/kippping	20 min 30 min 20 min
4	Dynamic articular stretching	Row 250 m Row 500 m Row 1000 m Row 500 m Row 250 m Rest 1 min between efforts	3 rounds
5	Articular mobility Hinge PVC overhead squats Medicine ball slams Bear walk Hindu push-ups 50 double-unders	100 single-unders 20 overhead squats 100 single-unders 12 ring dips 100 single-unders 20 dumbbell snatches 100 single-unders 12 chin-over bar pull-up	2 rounds, 1-min rest
6	Articular mobility Hinge PVC overhead squats Medicine ball slams Bear walk Hindu push-ups 50 burpees	Clean and jerk Bench press	3 × 5 5 × 5
7	Articular mobility Hinge PVC overhead squats Medicine ball slams Bear walk Hindu push-ups 50 goblet squats	Hero WOD Diane Deadlifts, 225 lb/155 lb (102 kg/70 kg) Handstand push-ups Deadlifts, 315 lb/205 lb (143 kg/93 kg) 50-ft (15-m) handstand walk after each set	3 × 21/15/9
8	Articular mobility Hinge PVC overhead squats Medicine ball slams Bear walk Hindu push-ups 50 box jumps	Dumbbell hang clean and jerks Weighted pull-ups	5 × 15/12/9/6/3
9	Articular mobility Hinge PVC overhead squats Medicine ball slams Bear walk Hindu push-ups 1-min plank	15-cal row Push-ups Ball wall	15 cal 15 As many sets as possible in 7 min 50 reps

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**Table 2. Continued From Previous Page**

Training Session	Warm-Up	Workout of the Day	Repetitions and Sets or Time
10	Articular mobility Hinge PVC overhead squats Medicine ball slams Bear walk Hindu push-ups	3 thrusters 3 chest-to-bar pull-ups 6 thrusters 6 chest-to-bar pull-ups 9 thrusters 9 chest-to-bar pull-ups 12 thrusters 12 chest-to-bar pull-ups 15 thrusters 15 chest-to-bar pull-ups 18 thrusters 18 chest-to-bar pull-ups	As many sets as possible in 7 min
11	Articular mobility Hinge PVC overhead squats Medicine ball slams Bear walk Hindu push-ups	Hero WOD Tama 800-m single-arm barbell farmers carry, 45 lb/35 lb (20 kg/16 kg) 31 toes-to-bars 31 push-ups 31 front squats, 95 lb/65 lb (43 kg/30 kg) 400-m single-arm barbell farmers carry, 95 lb/65 lb (43 kg/30 kg) 31 toes-to-bars 31 push-ups 31 hang power cleans, 135 lb/95 lb (61 kg/89 kg) 200-m single-arm barbell farmers carry, 135 lb/95 lb (61 kg/89 kg)	Complete as fast as possible
12	Articular mobility Hinge PVC overhead squats Medicine ball slams Bear walk Hindu push-ups	Hero double Helen Run 800 m 30 kettlebell swings 18 pull-ups	3 rounds of time scored

Abbreviation: PVC, polyvinyl chloride; WOD, workout of the day.

Participants performed 3 sets of 10 repetitions with a 1-minute rest between sets for all the exercises described above (see Figure 2 and Supplemental Video; video available online at <http://dx.doi.org/10.4085/1062-6050-181-18.S1>). All training sessions were monitored by a certified CrossFit instructor.

**Control Group.** Participants allocated to the control group received no intervention.

### Outcomes

Ankle-dorsiflexion range of motion was assessed by the WBLT. For this test, the participant stands facing a wall with the involved foot parallel to a tape measure that has been attached to the floor and the opposite leg placed

behind in tandem stance. A forward lunge is performed until the anterior knee contacts the wall with the heel firmly planted on the ground. The maximum distance the participant can position the foot away from the wall while keeping both the heel flat on the floor and the knee touching the wall is measured in millimeters between the part of the foot that is closest to the wall and the wall itself. Participants performed 3 practice runs and 3 test trials on the involved limb. The average of the 3 test trials was calculated and used for statistical analysis. The WBLT has been shown to have high intrarater ( $r = 0.99$ ) and interrater ( $r = 0.98$ ) reliability.<sup>18</sup> Furthermore, it has already been studied in patients with CAI, and the results were shown to correlate with dynamic postural-control measures.<sup>19</sup>



**Figure 2. Self-mobilization techniques. A, Band. B, Kettlebell. C, Double band.**



Dynamic balance was measured using a simplified version of the SEBT in the anterior-, posteromedial (PM)-, and posterolateral (PL)-reach directions.<sup>20</sup> Patients stood on a single leg with the involved limb at the center of a grid and maintained single-limb stance with both hands on the hips while trying to reach the farthest point possible in the anterior-, PM-, and PL-reach directions with the most distal part of the reach foot, while keeping slight toe contact on the tape measure.<sup>20,21</sup> The SEBT has been reported<sup>21</sup> to be a reliable and valid test for detecting reach deficits both between participants and between the sides of participants with unilateral ankle instability.

Self-reported ankle instability was determined using the CAIT, a 9-item questionnaire with reported discriminative properties for identifying and classifying the severity of ankle instability. This tool was recommended by the International Ankle Consortium.<sup>22,23</sup> The questionnaire is scored from 0 to 30, with lower scores indicating decreased stability and scores  $\leq 25$  indicating CAI.<sup>24</sup> The Spanish version of the CAIT has high internal consistency (Cronbach  $\alpha = 0.766$ ) and reliability (intraclass correlation coefficient = 0.979; 95% confidence interval [CI] = 0.958, 0.990).<sup>25</sup>

### Statistical Analysis

Descriptive statistics were used for the means and standard deviations of continuous variables and frequencies (percentages) for the categorical variables. We performed visual inspections of frequency distributions (histograms) and Shapiro-Wilk tests to confirm the normal distribution of the continuous variables. Concerning participant demographics and baseline measures, separate 1-way analyses of variance (ANOVAs) were performed for continuous variables and Kruskal-Wallis tests for categorical variables. This allowed us to examine the differences among the 3 groups: ankle-joint self-mobilization plus CrossFit, CrossFit alone, and control (no treatment). For each outcome variable (DFROM, SEBT, and CAIT), a 2-way ANOVA (group and time) with repeated measures was conducted to determine treatment effects among the groups. Post hoc Tukey honestly significant difference tests were performed to locate differences in the presence of significant interactions or main effects. To assess within-group effect sizes, change scores were calculated between preintervention and postintervention measurements with Cohen *d* effect sizes, which were computed by dividing the change score by the pooled standard deviation. Similarly, between-groups effect sizes were examined using change scores from postintervention measurements between 2 of the 3 groups along with the Cohen *d*. The strength-of-treatment effect was interpreted using the Cohen *d* effect size: *weak* if  $< 0.02$ , *small* if 0.2 to 0.05, *moderate* if 0.5 to 0.8, or *large* if  $> 0.08$ . The  $\alpha$  level was set a priori at  $P < .05$ . To compare intervention effects across groups, we calculated clinical epidemiologic measures such as probability, relative risk (RR), and numbers needed to treat (NNT).<sup>26</sup> We dichotomized participants as having successful or unsuccessful results based on the change from pre- to postintervention measurements for each outcome variable. A *success* was defined as a change that exceeded the minimal detectable change (MDC) for the WBLT (1.9 cm)<sup>27</sup> and SEBT (anterior = 1.56%, PM = 3.36%, PL =

4.28%)<sup>28</sup> or the minimal clinically important change on the CAIT (3 points).<sup>28</sup> Using the probability values for success (ie, success rate) within the group, we estimated the RR and NNT between 2 of the 3 groups for each outcome, along with their 90% CIs. The 90% CI has been recommended to serve as the 95% credibility interval and an alternative designation that contains the true effect magnitude.<sup>26</sup> Thus, the lower bound of the 90% CI would correspond to the lower limit of the 95% credibility interval that represents a 95% level of certainty about the smallest comparative effect magnitude for the RR point estimate, whereas the upper limit of the 95% CI for the NNT point estimate reflects the smallest effect. The strength of intervention effects (RR) was as follows: *small* if  $\geq 1.1$ , *moderate* if  $\geq 1.4$ , *large* if  $\geq 2.0$ , or *very large* if  $\geq 3.3$ . We used SPSS (version 24.0; IBM Corp, Armonk, NY) for tests of normality and baseline comparisons and an Excel (version 2016; Microsoft Corp, Redmond, WA) spreadsheet to calculate the RR and NNT with their 90% respective CIs.

### RESULTS

The groups did not differ in any demographic or baseline measures, indicating that they were similar in their demographic and clinical characteristics (Table 1). Pre-intervention and postintervention data for each outcome in all 3 groups are presented in Table 3 along with their group means changes. The self-mobilization plus CrossFit group improved in ankle motion (DFROM), dynamic balance (SEBT), and self-reported ankle stability (CAIT). These improvements were large as indicated by Cohen *d* measures greater than 1.52 and appeared to be true because the associated 95% CI did not cross zero (Table 4). Outcome measures for the CrossFit-alone group improved in comparison with the control group, but the strength-of-treatment effects on balance were somewhat smaller, as illustrated by effect sizes of less than 1 (moderate to large). As expected, the control group did not experience change in any of their outcome variables over time. In addition to the within-group treatment effects, both intervention groups displayed mostly large treatment effects (Cohen *d*  $> 1$ ) for all outcome variables when compared with the control group (Table 4).

Regarding the probability of successful results, both intervention groups were more associated than the control group with patients achieving the desirable clinical change (exceeding the MDC for DFROM and the SEBT) or benefit (exceeding the MDIC for the CAIT) for almost all outcomes (Table 5). The effects were at least moderate, given that the probability of success for a patient who was treated with either intervention was higher than for a patient who received no intervention. The 95% credibility lower limits for the RRs ensure that the success rates were at least 1.8 times greater in a patient who pursued the combination of self-mobilization and CrossFit for all outcome variables—and at least 2.3 times greater in a patient treated only with CrossFit except for 1 outcome variable (SEBT-PM) for which the effect was not clear as the associated CI crossed 1. In addition to the RR results, both interventions were beneficial: At most, 4 patients needed to be treated with self-mobilization plus CrossFit to see benefits in 1 patient for all outcome variables. On the other hand, except

**Table 3. Within-Group Change Scores Between Pre-and Postintervention Measurements<sup>a</sup>**

Outcomes	Group											
	Self-Mobilization Plus CrossFit				CrossFit				Control			
	Baseline	End of Intervention	Within-Group Change (95% CI)	Baseline	End of Intervention	Within-Group Change (95% CI)	Baseline	End of Intervention	Within-Group Change (95% CI)	Baseline	End of Intervention	Within-Group Change (95% CI)
Dorsiflexion range of motion	8.72 ± 1.19	11.00 ± 0.67	2.28 (1.74, 2.83)	8.97 ± 1.01	10.36 ± 0.98	1.40 (0.95, 1.84)	8.75 ± 0.83	8.71 ± 0.83	-0.04 (-0.09, 0.02)			
Star Excursion Balance Test score												
Anterior	75.14 ± 2.42	78.26 ± 1.60	3.11 (2.47, 3.75)	76.40 ± 2.97	78.17 ± 2.93	1.77 (1.38, 2.15)	74.80 ± 2.84	75.17 ± 2.83	0.37 (-0.10, 0.84)			
Posteromedial	89.92 ± 3.05	94.57 ± 2.56	4.65 (3.63, 5.67)	89.70 ± 4.20	92.63 ± 3.30	2.93 (2.15, 3.71)	89.22 ± 3.37	90.56 ± 3.80	1.34 (-0.15, 2.83)			
Posterolateral	86.85 ± 2.41	92.37 ± 2.82	5.52 (4.54, 6.50)	86.93 ± 4.04	90.44 ± 3.62	3.51 (1.94, 5.08)	87.90 ± 3.15	87.94 ± 3.25	0.04 (-0.48, 0.55)			
Cumberland Ankle Instability Tool score (range = 0–30)	18.84 ± 2.08	24.16 ± 1.65	5.32 (4.67, 5.97)	18.92 ± 1.84	23.29 ± 1.27	4.38 (3.53, 5.22)	19.00 ± 2.07	19.10 ± 2.07	0.10 (-0.25, 0.45)			

<sup>a</sup> Data are given as mean ± SD.

**Table 4. Between-Groups Effect Sizes**

Outcomes	Comparison					
	Self-Mobilization Plus CrossFit Versus Control		CrossFit Versus Control		Self-Mobilization Plus CrossFit Versus CrossFit	
	Between-Group Change (95% CI) <sup>a</sup>	Cohen d (95% CI)	Between-Group Change (95% CI)	Cohen d (95% CI)	Between-Group Change (95% CI)	Cohen d (95% CI) <sup>b</sup>
Dorsiflexion range of motion	2.29 <sup>c</sup> (1.84, 2.74)	3.07 (2.21, 3.92)	1.65 <sup>c</sup> (1.10, 2.20)	1.81 (1.11, 2.50)	0.64 <sup>c</sup> (0.16, 1.12)	0.77 (0.19, 1.35)
Star Excursion Balance Test score						
Anterior	3.09 <sup>c</sup> (1.75, 4.43)	1.38 (0.73, 2.02)	3.00 <sup>c</sup> (1.26, 4.74)	1.04 (0.42, 1.66)	0.09 (-1.26, 1.44)	0.04 (-0.52, 0.60)
Posteromedial	4.01 <sup>c</sup> (2.11, 5.91)	1.26 (0.62, 1.89)	2.07 <sup>c</sup> (-0.06, 4.20)	0.58 (-0.01, 1.18)	1.94 <sup>c</sup> (0.25, 3.63)	0.66 (0.08, 1.23)
Posterolateral	4.43 <sup>c</sup> (2.63, 6.23)	1.47 (0.81, 2.12)	2.50 <sup>c</sup> (0.42, 4.58)	0.72 (0.12, 1.33)	1.93 <sup>c</sup> (0.07, 3.79)	0.60 (0.02, 1.17)
Cumberland Ankle Instability Tool score (range = 0–30)	5.06 <sup>c</sup> (3.95, 6.17)	2.73 (1.93, 3.54)	4.19 <sup>c</sup> (3.17, 5.21)	2.48 (1.70, 3.26)	0.87 (0.02, 1.72)	0.59 (0.02, 1.16)

<sup>a</sup> Between-groups change scores were calculated using postintervention measurements between 2 of the 3 groups, with positive values indicating that the intervention listed first was more effective.

<sup>b</sup> Cohen d estimates of effect sizes were computed by dividing the change scores by the pooled standard deviations.

<sup>c</sup> A statistically significant change that was greater than the Tukey honestly significant difference.

Table 5. Epidemiologic Measures

Outcomes	Probability, % (Successes)				Relative Risk (or Success; 95% Credibility Interval)				NNT (95% Credibility Interval)			
	Self-Mobilization Plus CrossFit		Control		Self-Mobilization Plus CrossFit Versus CrossFit		Self-Mobilization Plus CrossFit Versus Control		Self-Mobilization Plus CrossFit Versus CrossFit		Self-Mobilization Plus CrossFit Versus Control	
	(n = 25)	(n = 24)	(n = 21)	(n = 21)	Versus CrossFit	Versus Control	Versus CrossFit	Versus Control	Versus CrossFit	Versus Control	Versus CrossFit	Versus Control
Dorsiflexion range of motion	56 (14)	19 (4)	0 (0)	0 (0)	3.4 (1.5, 7.5)	NA	NA	NA	3 (2–6 NNTB)	2 (1–3 NNTB)	6 (3–46 NNTB)	
Star Excursion Balance Test score												
Anterior	88 (22)	67 (16)	10 (2)	10 (2)	1.3 (1.1, 1.7)	9.2 (3.0, 28.1)	7.0 (2.3, 21.7)	7.0 (2.3, 21.7)	5 (3–64 NNTB)	1 (1–2 NNTB)	2 (1–3 NNTB)	
Posteromedial	64 (16)	33 (8)	14 (3)	14 (3)	1.9 (1.1, 3.3)	4.5 (1.8, 11.2)	2.3 (0.9, 6.3)	2.3 (0.9, 6.3)	3 (2–14 NNTB)	2 (2–4 NNTB)	5 (44 NNTH ∞ 3 NNTB)	
Posterolateral	68 (17)	21 (5)	0 (0)	0 (0)	3.3 (1.6, 6.5)	NA	NA	NA	2 (2–4 NNTB)	1 (1–2 NNTB)	5 (3–18 NNTB)	
Cumberland Ankle Instability Tool score (range = 0–30)	96 (24)	83 (20)	0 (0)	0 (0)	1.2 (0.9, 1.4)	NA	NA	NA	8 (42 NNTH ∞ 3 NNTB)	1 (1–2 NNTB)	1 (1–2 NNTB)	

Abbreviations: NA, not applicable; NNT, number needed to treat; NNTB, number needed to treat to benefit; NNTH, number needed to treat to harm.

for the SEBT-PM outcome, 46 patients needed to be treated with CrossFit alone to see improvement.

In comparing the 2 interventions, the combination of self-mobilization and CrossFit appeared to be superior to CrossFit alone for DFROM and SEBT but not for CAIT. The superior effects were small to moderate, and the probability (success rate) for a patient treated with self-mobilization and CrossFit was at least 1.1 times greater than for a patient receiving CrossFit alone. At most, 64 patients needed to be treated with self-mobilization and CrossFit to see benefits compared with CrossFit alone.

## DISCUSSION

Participants in both intervention groups showed high adherence to treatment, with only 1 dropout in the CrossFit-alone group and no reported adverse events. The results suggest that both interventions, ankle-joint self-mobilization plus CrossFit and CrossFit training alone, were effective in improving range of motion, dynamic balance, and self-reported ankle instability. Nevertheless, the magnitude of change of both treatment conditions differed depending on the variable.

Limited ankle dorsiflexion was present in those with CAI and associated with deficits in functional performance and balance.<sup>8</sup> Furthermore, DFROM restrictions are considered a risk factor that may increase the injury rate in other structures, such as the anterior cruciate ligament or Achilles tendon.<sup>29</sup> Improved DFROM has been observed after manual therapy and the use of instruments designed to enhance posterior gliding of the talus.<sup>30</sup> The self-mobilization exercises in our study, which were focused on posterior gliding of the talus and enhanced by the active movement of the patient, demonstrated large effects in improving DFROM (Cohen  $d = 3.07$ ); 56% of successful patients exceeded the MDC, and the NNT was 2 patients. These results agree with those of researchers<sup>7,8</sup> who determined that weight-bearing mobilization with movement was the most effective way to increase ankle DFROM. Although previous investigators did not use the WBLT as an outcome measure for ankle DFROM, after we estimated the equivalence between millimeters and angles, our results seem to be superior to those reported by Kang et al<sup>30</sup> and Jeon et al.<sup>9</sup> Nevertheless, 1 of our major findings was the improved DFROM in the CrossFit-alone group (Cohen  $d = 1.81$ ): 19% of participants exceeded the MDC, and the NNT was 6. To our knowledge, we are the first to study the influence of CrossFit in improving ankle DFROM. These findings could be explained by the reported effectiveness of some stretching protocols and the effects of the closed kinetic chain on talar displacement during a weight-bearing task.<sup>31</sup> As expected, the self-mobilization group displayed more improvement in ankle DFROM, with an NNT difference of 3 versus 46 patients compared with the CrossFit-alone group. Clinicians who seek to improve ankle DFROM in patients with CAI can now consider including self-mobilization and CrossFit training in their rehabilitation programs.

The influence of ankle-joint mobilization and strength training in improving dynamic postural control has been explored previously.<sup>4,6</sup> According to Kosik et al,<sup>4</sup> both interventions (self-mobilization plus CrossFit and CrossFit



alone) were linked with increases in the reach distances on the SEBT due to the influence of joint mobilization and strength training. The improved dynamic balance after 12 weeks of CrossFit training seems to be comparable with the results obtained after neuromuscular training.<sup>32</sup> Our NNT analysis revealed that both interventions can be considered excellent treatments for CAI, but the self-mobilization group achieved better scores than the CrossFit-alone group for the PM and PL reach directions of the SEBT (although not in the anterior direction). The ankle DFROM results of the self-mobilization group were also superior; modified balance-adaptation strategies in patients with CAI are a possible explanation for this finding.

In contrast with single-exercise strengthening programs in patients with CAI,<sup>32</sup> the CrossFit-based intervention does not focus only on the ankle joint. This functional approach may lead to additional benefits linked to the recruitment of larger muscle groups during multijoint exercises, which could positively influence the balance strategies of patients with CAI.<sup>15</sup> These results agree with those of Donovan et al,<sup>33</sup> who developed a multicomponent training protocol for patients with CAI and reported benefits in DFROM and balance.

Another important aspect of patients with CAI is the self-reported feeling of instability. We used the CAIT to assess the severity of the ankle instability of our participants. Previous investigators found that joint mobilization<sup>7</sup> and neuromuscular training<sup>11</sup> were effective in improving self-reported instability. After 12 weeks, the self-mobilization plus CrossFit and CrossFit-alone interventions resulted in similar improvements on the CAIT of >3 points, which has been established as the MDC for monitoring change over time.<sup>28</sup> The NNT value was 1 in both groups and therefore these interventions can be considered perfect treatments. The improvements of 96% and 83% of the participants in the self-mobilization plus CrossFit and CrossFit-alone groups, respectively, can be considered the greatest strength of the present study. In contrast with Shih et al,<sup>34</sup> who reported improvement on the CAIT only in the group allocated to the mobilization plus training protocol, we observed that both interventions were effective in improving self-reported ankle instability. Some of the exercises we included, such as box jumps, barbell lunges, and overhead squats, may be associated with enhanced self-confidence and an improved feeling of stability in patients with CAI. Our results suggest that CrossFit training should be considered an effective treatment option for patients with subjective ankle instability.

Further studies are needed to determine the effectiveness of CrossFit as a therapeutic approach in CAI. The choice of exercises, as well as the total training volume during the intervention, should both be addressed. Adding self-mobilization as a warm-up protocol in other sports could be beneficial when designing rehabilitation programs for patients with CAI. The major limitation of our research was the absence of a follow-up period to monitor the long-term effects of both interventions. The use of a self-reported function questionnaire such as the Foot and Ankle Ability Measure would have provided valuable information about ankle function, but no Spanish version was available at the time of this study.

## CONCLUSIONS

We are the first to examine the influence of self-mobilization and CrossFit in patients with CAI. The results suggest that a 12-week program of CrossFit-based training was effective in improving ankle DFROM, dynamic postural control, and self-reported instability. The addition of ankle-joint self-mobilization exercises to the CrossFit training produced additional benefits in ankle DFROM, as well as in PM and PL SEBT reach distances.

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## SUPPLEMENTAL MATERIAL

**Supplemental Video.** Self-mobilization techniques.

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