Systematic Review

Effect of Functional Rehabilitation on Performance of the Star Excursion Balance Test Among Recreational Athletes With Chronic Ankle Instability: A Systematic Review

Leanne Ahern, PT, MSc, Orla Nicholson, PT, MSc, Declan O’Sullivan, PT, MSc, Joseph G. McVeigh, PT, PhD

Discipline of Physiotherapy, School of Clinical Therapies, College of Medicine and Health, University College Cork, Cork, Ireland

Abstract

Objective: To determine (1) the effectiveness of rehabilitation for chronic ankle instability as measured by the Star Excursion Balance Test (SEBT) and (2) the relative efficacy and the long-term effects of these rehabilitation interventions.

Data Sources: Ten electronic databases were searched (2009-2019).

Study Selection: Included articles were randomized controlled trials in English investigating recreational athletes aged \( \geq 18 \) years with chronic ankle instability. At least 1 functional rehabilitation intervention had to be included and the SEBT test (or the modified version) used as an outcome measure.

Data Extraction: Two researchers (L.A., O.N.) extracted data regarding participant demographics; intervention characteristics; trial size; and results at baseline, postintervention, and at follow-up, where appropriate.

Data Synthesis: A systematic review and narrative synthesis was conducted. Methodological quality of included studies was assessed using the Cochrane Risk of Bias Tool and the van Tulder scale. The review was registered with PROSPERO (ID: 164468). Ten studies (n=368), 2 high-quality, 1 moderate-quality, and 7 low-quality, were included in the review. Interventions included balance training, strength training, vibration training, and mixed training. Results suggest that rehabilitation of chronic ankle instability that includes wobble board exercises (average percentage change: 14.3%) and hip strengthening exercises (average percentage change: 12.8%) are most effective. Few studies compared different types of rehabilitation for chronic ankle instability. However, improvements on the SEBT suggest that a rehabilitation program focusing on

KEYWORDS

Ankle; Postural Balance; Rehabilitation; Systematic Review

List of abbreviations: MDC, minimal detectable change; SEBT, Star Excursion Balance Test; WBVT, whole-body vibration training.

Disclosures: Joseph G. McVeigh serves as a Section Editor with Archives of Rehabilitation Research and Clinical Translation. The other authors have nothing to disclose.

Cite this article as: Arch Rehabil Res Clin Transl. 2021;3:100133

https://doi.org/10.1016/j.arrct.2021.100133

2590-1095/© 2021 The Authors. Published by Elsevier Inc. on behalf of American Congress of Rehabilitation Medicine. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).
A lateral ankle sprain involves the ankle rolling inward at a high velocity, damaging the lateral ligament complex.1–4 A total of 85% of lateral ankle sprains result from excessive inversion.2,5 Lateral ankle sprains account for approximately 30% of all injuries6–8 and frequently occur among sporting individuals.9–11 Lateral ankle sprains damage the mechanoreceptors in the tissues surrounding the ankle and12–15 potentially lead to residual pain, “giving away,” and functional impairments.16 Risk of reinjury is estimated up to 73%,17 with approximately 31%-40% developing chronic ankle instability.18,19 Lateral ankle sprains are linked to high economic costs and reduced work productivity,18 emphasizing the economic burden of this injury.

Chronic ankle instability commonly consists of reoccurring ankle sprain, residual symptoms, and episodes of “giving way”19 and encompasses functional and mechanical ankle instability.19 Functional instability incorporates muscle strength deficiencies and an impaired proprioceptive system.20,21 resulting in altered sensorimotor and postural control.21 Ankle sensorimotor control incorporates muscle activity, which influences ankle stability.22 Deficits in peronei muscle function are common after a sprain.23 These muscles prevent potential injury by resisting the inverting forces that may cause excessive inversion.24 Impaired dynamic postural control results from diminished strength, range of motion, neuromuscular control, and proprioception.17

The Star Excursion Balance Test (SEBT) is a widely used, reliable, and valid measure of dynamic postural control.25,26 It is an inexpensive, simple measure27 and has been extensively investigated among individuals with chronic ankle instability.17,28–34 A modified version, known as the Y Balance Test is also commonly used.35–40

Rehabilitation programs including balance,35,37,41–44 strength,37,39 vibration,45 and mixed training40,46,47 have been investigated. However, evidence is conflicting regarding which intervention type is the most efficacious.

Balance training improves an individual’s ability to maintain center of gravity and posture by challenging the vestibular and musculoskeletal systems.49 It has been reported that balance training can improve dynamic postural control among individuals with chronic ankle instability.43,49,50 McKeon et al.43 conducted a high-quality study investigating the effects of a 4-week balance program among adults with chronic ankle instability and reported significant improvements in the intervention group for self-reported disability and postural control.43

Strength training involves exerting force in an attempt to surmount resistance, leading to greater recruitment and stronger synchronization of muscle fibers,48 which improves neuromuscular control and muscular development.51–56 Smith et al.57 conducted a high-quality study investigating the effects of a 6-week strength program among individuals with chronic ankle instability. They reported significant improvements in evertor strength in the intervention group and concluded that an effective strength program should be challenging and multiplanar to improve strength and prepare the ankle for return to regular activity.57

Whole-body vibration training (WBVT) involves mechanical oscillations transmitted from a vibration platform that alters joint mechanoreceptors, muscle spindles, power, and strength performances,58 but there is limited research exploring WBVT for chronic ankle instability. Ray59 conducted a moderate quality meta-analysis (n=4) comparing the effectiveness of WBVT to wobble board rehabilitation. These authors concluded that wobble board training was more effective for improving dynamic postural control in recreational athletes with chronic ankle instability.

In 2010, Webster and Gribble60 systematically reviewed functional rehabilitation literature for chronic ankle instability (n=6 randomized controlled trials). Their findings suggested that all functional rehabilitation interventions significantly improved postural control.50 However, they did not compare interventions for their relative efficacy, nor did they assess follow-up periods to determine the long-term effects. This current review provides an up-to-date review of the most recent literature (the last 10 years) exploring the optimal rehabilitation parameters, as measured by the SEBT, to assist clinicians with the conservative management of chronic ankle instability.

The aim of this review is to determine the effectiveness of functional rehabilitation for improving dynamic postural control, as measured by the SEBT, among recreational athletes with chronic ankle instability, with specific consideration for the relative efficacy and long-term effects of interventions.

Methods

This review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.61 The review protocol was registered with
Data sources and searches

Two researchers (L.A., O.N.) conducted an electronic search of 10 databases from 2009-2019 to update the literature after the last systematic review60 conducted on the topic.

Box 1 displays the databases searched and the keywords used. Reference lists of relevant articles were checked to identify further eligible studies. Titles and abstracts of potential eligible studies were screened (L.A., O.N.). Any disagreements were resolved by an additional researcher (D.O. or J.M.).

Box 1  Search Strategy

Databases:
- EBSCO
- MEDLINE
- SPORTDiscus
- CINAHL
- Web of Science
- PubMed
- Embase
- Scopus
- Google Scholar
- Cochrane Library
Search keywords:
1. [reach OR performance]
2. [“chronic ankle instability” OR cai OR “functional instability” OR “non-copers”]
3. [“star excursion balance test” OR sebt OR “Y balance test”]
4. [functional rehabilitation” OR intervention OR exercise OR “closed-chain exercise”]
5. 1 AND 2 AND 3 AND 4
6. [“randomized controlled trial”]
7. 5 AND 6

Study selection

Full-text randomized control trials published in English were included. For the purposes of this review recreational athletes were self-reported or defined as completing at least 20 minutes of moderate to high intensity physical activity 3 times per week.62 It is recognized, however, that the definition of recreational athletes varies across studies. Brown et al,62 for example, defined recreational athletes as those who participate in at least 20 minutes of physical activity 2 times per week. However, Ray69 defined recreational athletes as individuals participating in more than 1.5 hours of moderate to vigorous physical activity per week. A previous study by Sierra-Guzman et al47 did not even define recreational athletes. Functional rehabilitation was defined as “dynamic, closed-kinetic-chain activity other than quiet standing.”37(p99) Included trials were required to report the SEBT or Y Balance Test reach performances. Both short-term (6-12wk) and long-term (12+wk) follow-up studies were included.

Table 1 displays the eligibility criteria for the included studies. The primary outcome of interest was improvements in the SEBT performances, expressed as a percentage of change relative to preintervention.

Data extraction

Two researchers (L.A., O.N.) extracted data regarding participant demographics, intervention characteristics, trial size, baseline and postintervention results, and follow-up results where relevant.

Risk of bias assessment

Two independent reviewers (L.A., O.N.) assessed each study using the Cochrane Risk of Bias Tool63 and the van Tulder scale.64,65 As recommended in the Cochrane Handbook for Systematic Reviews of Interventions65 the Cochrane Risk of Bias Tool was used to assess 5 issues associated with risk of bias: sequence generation, allocation concealment, blinding of personnel and outcome assessors, incomplete outcome data, selective reporting, and additional possible threats to validity not previously identified. The van Tulder scale was also included because it assesses both compliance and timing of outcome assessments. Any ambiguity was discussed and a consensus reached, and disagreements were resolved by further discussion with D.O. or J.M.

Quality assessment

Data synthesis

The data synthesis was conducted following the recommended standards of performance outlined by Eden et al66: description of the methodological characteristics of selected trials; strengths and limitations of each trial; how the limitations may have influenced the results; the relationship between the study characteristics and reported findings; and the relevance of each trial to its population, control, and outcomes of interest (table 2). Because there are numerous interventions used in the management of chronic ankle instability, with substantial clinical heterogeneity between studies, a meta-analysis was not conducted.

Quantifying the magnitude of results

The minimal detectable change (MDC) values outlined by Munro et al67 (table 3) were chosen because they include the complete SEBT rather than a subsection and are more conservative. The average percentage change was calculated from the reach distances reported in the studies and compared with the average MDC value for those reach directions.
Study selection

Figure 1 displays the search results and explanations for exclusion. After the database and hand searches, 343 articles were identified; 24 full-text articles were assessed. Ten articles (2010-2018) featuring 368 participants were suitable for this review. Table 4 displays the study characteristics of the included articles.

Description of studies

All studies provided demographic details and included 177 male and 191 female participants (mean weighted age, 23y) (see table 4). Four studies involved unilateral chronic ankle instability, 39,40,45,46 and 6 investigated unilateral and bilateral chronic ankle instability. 35-38,44,47 Comprehensive baseline and follow-up data were presented in most cases (table 5).

Control groups included normal activity,38,45,47 general activity with strength training,40 bicycle workout,37 conventional physiotherapy,46 no intervention,39,44 or an active comparator.35,36 Two studies included a follow-up period, both short-term.36,47

Risk of bias

Tables 6 and 7 present the outcomes of the Cochrane Risk of Bias tool and the van Tulder scale. The mean score of the van Tulder scale was 5.1 of 11. Five studies had a high risk of bias,37,38,44-46 potentially caused by inadequate participant instability, 39,40,45,46 and 6 investigated unilateral and bilateral chronic ankle instability. 35-38,44,47 Comprehensive baseline and follow-up data were presented in most cases (table 5).

Control groups included normal activity,38,45,47 general activity with strength training,40 bicycle workout,37 conventional physiotherapy,46 no intervention,39,44 or an active comparator.35,36 Two studies included a follow-up period, both short-term.36,47

Results

Table 1  Eligibility criteria

| Inclusion Criteria | Exclusion Criteria |
|--------------------|--------------------|
| Study design: randomized control trials | Trials were excluded if the recruited participants involved any of the following conditions: |
| Population of interest: Recreational athletes, any sex, aged 18+ y with CAI | - Aged <18 y |
| Intervention: At least 1 form of functional rehabilitation (eg, balance, strength, vibration, mixed training) | - Not recreational athletes |
| Comparison or control group: Control group was required to fulfill at least 1 of the following conditions: | - Injury <4 wk ago |
| a) Recreational athletes without CAI | - Multiple injuries |
| b) An active comparator, usual care, or a sham group | - Nonfunctional CAI |
| c) If the entire sample consisted of recreational athletes with unilateral CAI, the contralateral uninjured limb was the control, or | - Neurologic impairments |
| d) If the entire sample involved recreational athletes with bilateral CAI, the control limb was specified. | - Vestibular impairments |
| - Upper respiratory infection |
| - Ear infection |
| - Other conditions that affect balance |
| - Previous stabilization procedure |
| - Previous fixation surgery. |
| Other reasons for exclusion included the following: | |
| - Control criteria not met |
| - Postintervention results not reported |
| - Full-text article not available |

Abbreviation: CAI, chronic ankle instability.

Table 2  Quality Assessment Guidelines

| Criteria used to determine the quality of the evidence | Classification |
|------------------------------------------------------|---------------|
| 1. Adequate randomization | High quality |
| 2. Adequate allocation concealment | Moderate quality |
| 3. Blinding of assessors | Low quality |
| 4. Intent-to-treat-analysis | |
| 5. Measurement of compliance | |

| Classification | Met 4 of the above 5 criteria (including allocation concealment) and scored at least 5/11 on the van Tulder scale. |
|---------------|--------------------------------------------------|
| High quality  | Met 3 of the 5 criteria and scored at least 5/11 on the van Tulder scale. |
| Moderate quality | Met ≤2 of the 5 criteria and scored <5/11 on the van Tulder scale. |

| Direction | % |
|-----------|---|
| Anterior  | 6.87 |
| Anteromedial | 6.13 |
| Anterolateral | 7.71 |
| Medial | 7.40 |
| Lateral | 7.68 |
| Posterior | 7.73 |
| Posteromedial | 3.36 |
| Posterolateral | 4.28 |
| Composite | 7.7 |
| Complete SEBT average | 6.4 |
| SEBT (A, AM, MED, PM, PL) average | 5.61 |
| Y-balance (A, PM, PL) average | 4.48 |
| Y-balance (AM, MED, PM) average | 5.63 |

Abbreviations: A, anterior; AM, anteromedial; MED, medial; PL, posterolateral; PM, posteromedial.

- MDC values developed by Hall et al.38
- Manually calculated average MDC values for specific directions based on MDC values outlined by Munro et al.67
Fig 1  PRISMA flowchart. Abbreviations: CAI, chronic ankle instability; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.
| Author(s) | Sample Size | Sex | Age (y), mean ± SD | Intervention Type | Treatment Limb | Dosage | Comparison/Control Group | Outcome Measure | Follow-up/Duration | Results/Comments | Conclusions | Limitations |
|-----------|--------------|-----|-------------------|------------------|----------------|--------|--------------------------|----------------|-------------------|-----------------|-------------|-------------|
| Anguish and Sandrey | 35 M:16 F:2 | 18.38 ± 1.81 | PHSB: Exercises included 1) SL hops to stabilization in 4 different directions, 2) Hop to stabilization and reach, 3) Unanticipated hop to stabilization, and 4) SLS activities with eyes open and closed and on compromising surfaces. | Affected limb If a participant reported bilateral ankle instability, the self-reported worse limb was used for training and analysis | 30-min supervised sessions, 3 times/wk for 4 wk | SLB: 1) SLs for 60 s, 2) SLs with a bail toss, 3) SLs kicking against resistance in 4 directions, and 4) Step-downs with the single limb in 4 directions. | NA | Y Balance Test | Within-group differences in both groups showed a significant improvement for 3 SEBT reach directions (P < 0.001). Reach distances increased after both balance training interventions with large (PL direction) and moderate to large (A and PM directions) ESs. Between-group ESs were small for all directions, and all 95% CIs crossed 0. A: ES = 0.20; 95% CI, 0.72 to 1.13 (favors PHSB group). PM: ES = 0.20; 95% CI, 1.13 to 0.73 (favors SLB group). PL: ES = 0.18; 95% CI, 1.11 to 0.75 (favors SLB group). | 1. Results cannot be generalized to other participants with CAI because of small sample size. 2. Lack of participant blinding. 3. No follow-up performed; therefore, the extent to which improvements might lead to a reduction in ankle sprains is unknown. |
| Bural et al | 24 M:7 F:17 | 21.3 ± 2.0 | Balance sessions included 1) Hop to stabilization in 4 directions, 2) Hop to stabilization and reach in 4 directions, 3) Unanticipated hop to stabilization, 4) Progressive SLS activities, and 5) Progressive SLS activities with eyes closed. | Affected limb If an individual had bilateral instability, the limb with lower FAAM and FAAM-S scores was used as the treatment limb. | 20-min supervised sessions performed 3 times/wk for 4 wk | 5-min set of STARS treatments including calf stretching, plantar massage, ankle joint mobilizations, and ankle joint traction performed before balance session. | 1 wk | Y Balance Test | Between-group ESs ranged from −0.41 for the A direction (favoring the Balance Training group) to 0.25 for PL direction (favoring Balance Training STARS group) immediately posttest; all between-group ESs had 95% CIs that crossed 0. A: ES = 0.79; 90% CI, 0.10 to 1.49 (favors Balance Training group). PM: ES = 0.89; 90% CI, 0.19 to 1.60. PL: ES = 0.85; 90% CI, 0.15 to 1.55. Balance Training group: A: ES = 0.54; 90% CI, −0.14 to 1.23. PM: ES = 1.43; 90% CI, 0.68 to 2.18. PL: ES = 1.35; 90% CI, 0.60 to 2.09. 1-wk follow-up: Balance Training group: A: ES = 0.49; 90% CI, −0.20 to 1.17. PM: ES = 0.92; 90% CI, 0.21 to 1.62. PL: ES = 1.47; 90% CI, 0.71 to 2.22. Balance Training STARS group: A: ES = 0.25. 90% CI, −0.43 to 0.92. PM: ES = 0.42; 90% CI, −0.26 to 1.10. PL: ES = 1.15; 90% CI, 0.43 to 1.88. 1. Small sample size. 2. Lack of participant blinding. 3. Time points of follow-up assessment need to be expanded for future research. |
| Cloak et al | 38 F:38 | 19 ± 1.1 | WBVT with single-leg exercises on a vibration platform (SL heel raises, SL squats). | Affected limb 1 session/wk with increasing duration and frequency over 6 wk. Wk 1 & 2: 30 Hz for 10 min Wk 3 & 4: 35 Hz for 12 min Wk 5 & 6: 40 Hz for 14 min | Normal training regimen; refrained from ankle specific strength/balance training for 6 wk. | SEBT | NA | SEBT NA | Significant improvements in A (P < 0.016), AM (P < 0.038), MED (P < 0.047), and AL (P < 0.015) directions in WBVT group compared with control group. No significant between-group differences in PM (P = 0.23), P (P = 0.58), PL (P = 0.23), and L (P = 0.19) directions. | 1. No follow-up performed. 2. Sample only included dancers. 3. All female sample. | (continued) |
| Article | Sample Size | Sex | Age (y), mean ± SD | Intervention Type | Treatment Limb | Dosage | Comparison/Control Group | Outcome Measure | Follow-up/Duration | Results/Comments | Limitations |
|---------|-------------|-----|-------------------|------------------|----------------|--------|------------------------|----------------|----------------|----------------|-------------|
| Cruz-Diaz et al.40 | 70 | M:35 | F:35 | 30.68 ± 9.37 | General strength and coordination training for lower body with additional balance training including 1) Exercise mats (SLS on different surface), 2) Dynair (DLS or SLS, with added throwing exercises), 3) BOSU (same as Dynair), 4) Mini trampoline (same as Dynair), 5) Foam roller (DLS or SLS started with half foam roller and progressed to classic foam roller; added throwing exercises), 6) Resistance bands (resisted DF, PF, INV, and EVN), and 7) Ankle disc (same as Dynair). | Affected limb | 3 sessions/wk for 6 wk with progression in intensity every 2 wk, 45 s work to 30 s rest; circuit was completed twice. | General activity combined with strength training for general lower body; instructed to avoid balance training tasks. | Y Balance Test | NA | Within-group differences in experimental group showed a significant improvement for the 3 reach directions (P < .001). ESs were moderate in A direction and larger in PH and PL directions in experimental groups, and 95% CIs did not cross 0 for any direction. A: ES=0.66; 95% CI, 0.263 to 1.06 PH: ES=1.38; 95% CI, 0.946 to 3.70 PL: ES=1.81, 95% CI, -0.62 to 3.24. Between-group differences in change scores were significant for all distances (P < .001). 1. No follow-up performed. |
| Hall et al.38 | 39 | M:17 | F:22 | 18.9 ± 1.3 | Strength: resistance band exercises for DF, PF, INV, and EVN. PNF: concentric contraction of the antagonist followed by a concentric contraction if the agonist. D1: dorsiflexion-inversion and plantarflexion-eversion. D2: dorsiflexion-eversion and plantarflexion-inversion. | Affected limb If an individual had bilateral instability, the ankle with the highest score on the functional ankle instability questionnaire was considered the treatment limb. | 3 sessions/wk for 6 wk | Regular activities avoiding strength or rehabilitative ankle exercises for 6 wk. | Y Balance Test | NA | Composite Y Balance Test did not demonstrate a significant time-by-group interaction (P=0.8). Neither RBP nor PNF group improved from pretest to posttest. ESs were moderate in both groups, and all 95% CIs crossed 0. RBP: ES=0.66; 95% CI, -0.2 to 1.4 PNF: ES=0.66; 95% CI, -0.2 to 1.4. 1. No follow-up performed. 2. Results displayed as composite score, giving little insight regarding specific direction. 3. Order of reaching directions was not randomized, which may have influenced participants' performance-learning effect. |
| 39 | M:21 | F:18 | BTP: 23.5 ± 6.5 | STP: 24.6 ± 7.7 | Control 24.8 ± 9.0 | BTP: Exercises included 1) Hop to stabilization, 2) Hop to stabilization and reach, 3) Hop-to-stabilization box drill, 4) Progressive SLS activities with eyes open, and 5) Progressive SLS activities with eyes closed. STP: Based on the RBP. | Affected limb If an individual had bilateral instability, the ankle with the highest score on the functional ankle instability questionnaire was considered the treatment limb. | 20-min session, 3 times/wk for 6 wk | Mild to moderately strenuous bicycle workout. | Y Balance Test | NA | Within-group differences were noted for both experimental groups (BTP: P < .001; STP: P < .001). ESs were large for BTP (Hedges’ g=0.71) and STP (Hedges’ g=0.60) groups. 1. Researchers were not blinded to group allocation. |

(continued)
| Article | Sample Size | Sample Sex | Age (y), mean ± SD | Intervention Type | Treatment Limb | Dosage | Comparison/Control Group | Outcome Measure | Follow-up/Duration | Results/Comments | Conclusions | Limitations |
|---------|-------------|------------|-------------------|------------------|----------------|--------|-------------------------|----------------|-------------------|-----------------|-------------|-------------|
| Linens et al 44 | 34 M:6 F:28 | Exp: 22.94±2.77 Control: 23.18±3.64 | and PNF strength protocol used by Holl et al 22 with the addition of single-leg heel raises on a step. | Wobble board rehabilitation: 5 levels were available for training with the height of each increased by half inches, heights ranges between 1 and 3 inches. | Affected limb if an individual had bilateral instability, the more symptomatic ankle was chosen. | 3 times/wk for 4 wk Five 40-s trials were completed with 1 min of rest in between trials. | No intervention. | SEBT | NA | Within-group differences in experimental group showed a significant improvement for the 3 reach directions (AM: P=0.01; MED: P=0.001; PL: P=0.011). Between-group differences were significant for AM direction (P=0.042) but not significant for MED (P=0.173) or PL (P=0.165) directions. Group-by-time interaction showed significant improvements for the 3 reach directions (P=0.005). | 1. All male participants. 2. No follow-up performed. | 1. The researcher administering the pre-posttest measurements was not blinded to participants’ group allocation. 2. Units of measurement were not reported; parameters of calculation were not reported. |
| Melam et al 46 | 30 M:30 | Exp: 21.0±2.2 Control: 21.3±2.3 | 1) Elastic tubing (front pull, back pull, crossover, reverse cross over) and 2) Physiotherapy conventional exercise program: - Range of motion and stretching exercises - Balance board activities - Heel and toe walking - Tandem walking. | Unaffected limb Affected limb was weight-bearing foot during exercises. | 4 times/wk for 4 wk. 4 sets of 20 reps. | Regular conventional physiotherapy program. | SEBT | NA | | | 1. Small sample size, might not have been adequate to detect post-intervention differences among groups. 2. Participants were not blinded to group allocation. |
| Author(s) | Sample Size | Sex | Age, mean ± SD | Intervention Type | Treatment Limb | Dosage | Comparison/Control Group | Outcome Measure | Follow-up/Duration | Results/Comments | Limitations |
|-----------|-------------|-----|----------------|-------------------|----------------|--------|------------------------|----------------|-------------------|----------------|------------|
| Smith et al. | 26 | M:12 | F:14 | Hip strength protocol using progressive resistance exercises with TheraBand for hip internal rotation and abduction | Affected limb | 3 times/wk for 4 wk, 3 sets of 20 reps. | No Intervention. Participants were not allowed to engage in new lower extremity rehabilitation for the duration of the study. | Y Balance Test | NA | In the NVIB group, moderate to large ESs were shown between pre- and immediately postintervention: MED: ES=0.78; 95% CI, 2.34 to 9.27 PM: ES=0.83; 95% CI, 2.38 to 11.79 PL: ES=0.43; 95% CI, 0.32 to 8.37 Composite: ES=0.58; 95% CI, 2.04 to 7.22. Decreases between immediately postintervention and follow-up were noted: A: ES=–0.40; 95% CI, –6.25 to –0.70 AM: ES=–0.39; 95% CI, –4.76 to –0.96 MED: ES=–0.47; 95% CI, –6.81 to 1.64 PM: ES=–0.40; 95% CI, –6.60 to –0.60 and PL: ES=–0.35; 95% CI, –6.37 to –0.60 and Composite: ES=–0.41; 95% CI, –5.24 to –1.95. Between-group differences were significant for A (P<.01), PM (P<.01), and PL (P<.01) directions. Within-group changes in experimental group showed a significant improvement for the 3 reach directions (P<.001). Within-group displayed moderate to large ES, and 95% CI did not cross 0 for any direction for intervention group. A: ES=0.8; 95% CI, 0.0 to 1.6 PM: ES=1.1; 95% CI, 0.3 to 2.3 PL: ES=0.9; 95% CI, 0.1 to 1.7. 1. The assessing clinician was not blinded to the group allocation of the participants. | | 0.48. | | | | |

Abbreviations: A, anterior; AL, anterolateral; AM, anteromedial; BTP, balance training protocol; CAI, chronic ankle instability; CAIT, Cumberland Ankle Instability Tool; CI, confidence interval; DF, dorsiflexion; DLS, double-limb stance; D1, diagonal 1 movement pattern; D2, diagonal 2 movement pattern; ES, effect size; EVN, eversion; Exp, experimental group; F, female; FAAM, Foot and Ankle Ability Measure; FAAM-S, Foot and Ankle Ability Measure–Sport; INV, inversion; L, lateral; M, male; MED, medial; NA, not applicable; NVIB, nonvibration; P, posterior; PA, physical activity; PF, plantarflexion; PHSB, progressive hop-to-stabilization balance; PL, posterolateral; PM, posteromedial; PNF, proprioceptive neuromuscular facilitation strength protocol group; RBP, resistance band protocol; SL, single-limb; SLB, single-limb balance; SLS, single-limb stance; STARS, sensory-targeted ankle rehabilitation strategies; STP, strength training protocol; VIB, vibration.
## Table 5 Data extracted from studies and calculated percentage change

| Author(s) | A | AL | L | PL | P | PM | MED | AM | Composite | SEBT Reach Directions | SEBT Reach | Calculated Percentage Change (%) | Corresponding Average MDC Value (Table 4) (%) |
|-----------|---|----|---|----|---|----|-----|----|------------|------------------------|------------|----------------------------------|---------------------------------------------|
| **Intervention Group Baseline Scores, mean ± SD, measurements are normalized to leg length (%)** | | | | | | | | | | | | | |
| **Author(s)** | **A** | **AL** | **L** | **PL** | **P** | **PM** | **MED** | **AM** | **Composite** | **A** | **AL** | **L** | **PL** | **P** | **PM** | **M** | **AM** | **Average** | **PHB** | **SLB** | **VIB** | **NVIB** | **RBP** | **PNF** | **C19** |
| Anguish and Sandrey | PHSB: | 87.43±4.39 | 88.96±3.50 | 97.98±4.36 | 89.31±5.71 | 89.61±6.71 | 5.58 | 4.31 | 4.89 | 87.43±4.39 | 88.96±3.50 | 97.98±4.36 | 89.31±5.71 | 89.61±6.71 | 5.58 | 4.31 | 4.89 | 4.48 |
| Burcal et al | BT: | 63.36±9.34 | 75.67±11.88 | 79.67±8.91 | 4.77 | 5.8 | 8.76 | 9.02 | 8.94 | 4.77 | 5.8 | 8.76 | 9.02 | 8.94 | | | | 4.48 |
| Cloak et al | SLB: | 63.07±6.00 | 71.60±10.35 | 77.43±7.73 | 19.56 | 8.79 | 9.41 | 12.11 | 9.67 | 19.56 | 8.79 | 9.41 | 12.11 | 9.67 | | | | 4.48 |
| Cruz-Diaz et al | BT: | 76.47±5.13 | 78.99±1.51 | 82.35±2.55 | 6.23 | 5.67 | 5.79 | 5.67 | 5.26 | 6.23 | 5.67 | 5.79 | 5.67 | 5.26 | | | | 4.48 |
| Hall et al | BT: | 88.96±3.50 | 97.98±4.36 | 89.31±5.71 | 5.58 | 4.31 | 4.89 | 87.43±4.39 | 88.96±3.50 | 97.98±4.36 | 89.31±5.71 | 89.61±6.71 | 5.58 | 4.31 | 4.89 | 4.48 |
| Hall et al | BT: | 84.9±19.88 | 87.7±7.43 | 88.9±9.95 | 8.76 | 9.02 | 8.76 | 9.02 | 8.94 | 8.76 | 9.02 | 8.76 | 9.02 | 8.94 | | | | 4.48 |
| Linens et al | BT: | 68.91±7.94 | 82.82±11.02 | 80.7±6.97 | 0.10* | 0.92 | 0.11* | 0.92 | 0.11* | 0.10* | 0.92 | 0.11* | 0.92 | 0.11* | | | | 5.63 |
| Sierra-Guzman et al | VIB: | 83.42±7.32 | 88.7±6.05 | 86.7±7.48 | 15.2 | 16.8 | 10.8 | 14.3 | 14.3 | 15.2 | 16.8 | 10.8 | 14.3 | 14.3 | | | | 5.63 |
| Smith et al | VIB: | 85.7±8.6 | 83.0±14.1 | 83.9±10.9 | 98.77±3.37 | 98.89±8.57 | 98.16±7.76 | 97.38±7.27 | | | | | | | | | | | |
| **Corresponding Average MDC Value (Table 4) (%)** | | | | | | | | | | | | | | | | | | | | |
| **Author(s)** | **A** | **AL** | **L** | **PL** | **P** | **PM** | **M** | **AM** | **Composite** | **A** | **AL** | **L** | **PL** | **P** | **PM** | **M** | **AM** | **Average** | **PHB** | **SLB** | **VIB** | **NVIB** | **RBP** | **PNF** | **C19** |
| Anguish and Sandrey | PHSB: | 87.43±4.39 | 88.96±3.50 | 97.98±4.36 | 89.31±5.71 | 89.61±6.71 | 5.58 | 4.31 | 4.89 | 87.43±4.39 | 88.96±3.50 | 97.98±4.36 | 89.31±5.71 | 89.61±6.71 | 5.58 | 4.31 | 4.89 | 4.48 |
| Burcal et al | BT: | 63.36±9.34 | 75.67±11.88 | 79.67±8.91 | 4.77 | 5.8 | 8.76 | 9.02 | 8.94 | 4.77 | 5.8 | 8.76 | 9.02 | 8.94 | | | | 4.48 |
| Cloak et al | SLB: | 63.07±6.00 | 71.60±10.35 | 77.43±7.73 | 19.56 | 8.79 | 9.41 | 12.11 | 9.67 | 19.56 | 8.79 | 9.41 | 12.11 | 9.67 | | | | 4.48 |
| Cruz-Diaz et al | BT: | 76.47±5.13 | 78.99±1.51 | 82.35±2.55 | 6.23 | 5.67 | 5.79 | 5.67 | 5.26 | 6.23 | 5.67 | 5.79 | 5.67 | 5.26 | | | | 4.48 |
| Hall et al | BT: | 88.96±3.50 | 97.98±4.36 | 89.31±5.71 | 5.58 | 4.31 | 4.89 | 87.43±4.39 | 88.96±3.50 | 97.98±4.36 | 89.31±5.71 | 89.61±6.71 | 5.58 | 4.31 | 4.89 | 4.48 |
| Hall et al | BT: | 84.9±19.88 | 87.7±7.43 | 88.9±9.95 | 8.76 | 9.02 | 8.76 | 9.02 | 8.94 | 8.76 | 9.02 | 8.76 | 9.02 | 8.94 | | | | 4.48 |
| Linens et al | BT: | 68.91±7.94 | 82.82±11.02 | 80.7±6.97 | 0.10* | 0.92 | 0.11* | 0.92 | 0.11* | 0.10* | 0.92 | 0.11* | 0.92 | 0.11* | | | | 5.63 |
| Sierra-Guzman et al | VIB: | 83.42±7.32 | 88.7±6.05 | 86.7±7.48 | 15.2 | 16.8 | 10.8 | 14.3 | 14.3 | 15.2 | 16.8 | 10.8 | 14.3 | 14.3 | | | | 5.63 |
| Smith et al | VIB: | 85.7±8.6 | 83.0±14.1 | 83.9±10.9 | 98.77±3.37 | 98.89±8.57 | 98.16±7.76 | 97.38±7.27 | | | | | | | | | | | |
| **Abbreviations:** A, anterior; AL, anterolateral; AM, anteromedial; BT, balance training; BTS, balance training with sensory-targeted ankle rehabilitation strategies; L, lateral; MED, medial; NVIB, nonvibration; P, posterior; PL, posterolateral; PHSB, progressive hop-to-stabilization balance; PM, postero medial; PNF, proprioceptive neuromuscular facilitation strength protocol group; RBP, resistance band protocol; SLB, single-limb balance; VIB, vibration. | | | | | | | | | | | | | | | | | | | | |
| *Units of measurement not reported.* | | | | | | | | | | | | | | | | | | | | |
### Table 6  Outcomes of Cochrane Risk of Bias Tool

| Author(s)                  | Random Sequence Generation | Allocation Concealment | Blinding (Participants and Personnel) | Blinding (Outcome Assessor) | Addressed Incomplete Outcome Data | Free of Selective Reporting | Free of Other Sources of Bias | High/Moderate/Low Risk |
|---------------------------|---------------------------|------------------------|---------------------------------------|-----------------------------|-----------------------------------|------------------------------|---------------------------|------------------------|
| Anguish and Sandrey 35    | Y                         | Y                      | N                                     | N                           | Y                                 | Y                           | U                         | Low                    |
| Burcal et al 36           | Y                         | Y                      | N                                     | N                           | Y                                 | Y                           | N                         | Moderate               |
| Cloak et al 45            | U                         | N                      | N                                     | U                           | Y                                 | Y                           | Y                         | High                  |
| Cruz-Diaz et al 40        | Y                         | Y                      | N                                     | Y                           | Y                                 | Y                           | Y                         | Low                   |
| Hall et al 38             | U                         | N                      | U                                     | N                           | Y                                 | Y                           | N                         | High                  |
| Hall et al 37             | U                         | N                      | N                                     | Y                           | N                                 | Y                           | N                         | High                  |
| Linens et al 44           | U                         | U                      | U                                     | N                           | U                                 | U                           | U                         | High                  |
| Melam et al 46            | U                         | U                      | U                                     | U                           | U                                 | U                           | U                         | High                  |
| Sierra-Guzmán et al 47    | Y                         | Y                      | N                                     | Y                           | Y                                 | Y                           | Y                         | Low                   |
| Smith et al 39            | Y                         | N                      | N                                     | Y                           | Y                                 | Y                           | N                         | Moderate               |

Abbreviations: N, no; U, unclear; Y, yes.

### Table 7  Outcomes of van Tulder scale

| Author(s)                  | Randomization | Allocation Concealment | Similar Baseline Characteristics | Patient Blinding | Investigator Blinding | Outcome Assessor Blinding | Cointervention Avoided | Compliance Acceptable | Dropout Rate Addressed | Intention-to-Treat Analysis | End Point (Similar Outcome Timing) | Total |
|---------------------------|---------------|------------------------|----------------------------------|------------------|-----------------------|--------------------------|------------------------|------------------------|------------------------|-------------------------------|---------------------------------|-------|
| Anguish and Sandrey 35    | Y             | Y                      | U                                | N                | Y                     | N                        | N                      | Y                      | Y                      | Y                             | Y                               | 7     |
| Burcal et al 36           | Y             | Y                      | Y                                | N                | N                     | N                        | Y                      | U                      | U                      | Y                             | U                               | 5     |
| Cloak et al 45            | U             | N                      | Y                                | N                | N                     | N                        | Y                      | Y                      | Y                      | Y                             | U                               | 3     |
| Cruz-Diaz et al 40        | U             | N                      | Y                                | N                | N                     | N                        | Y                      | Y                      | Y                      | Y                             | U                               | 7     |
| Hall et al 38             | U             | N                      | Y                                | U                | N                     | N                        | Y                      | Y                      | Y                      | Y                             | U                               | 5     |
| Hall et al 37             | U             | N                      | U                                | N                | N                     | N                        | Y                      | Y                      | Y                      | Y                             | U                               | 4     |
| Linens et al 44           | U             | U                      | Y                                | U                | U                     | N                        | N                      | U                      | N                      | Y                             | U                               | 4     |
| Melam et al 46            | U             | U                      | Y                                | U                | U                     | U                        | Y                      | U                      | N                      | Y                             | U                               | 3     |
| Sierra-Guzmán et al 47    | Y             | Y                      | Y                                | N                | Y                     | N                        | Y                      | U                      | N                      | Y                             | U                               | 8     |
| Smith et al 39            | Y             | N                      | Y                                | N                | N                     | N                        | Y                      | U                      | Y                      | N                             | U                               | 5     |

Abbreviations: N, no; U, unclear; Y, yes.
Blinding, which is difficult to achieve with exercise interventions. This should be considered when interpreting these results. Common methodological shortcomings were inadequate allocation concealment and inadequate blinding of assessors and participants. Only 4 studies reported both randomization and allocation concealment. Further shortfalls were lack of intention-to-treat analysis and failure to measure compliance.

Quality assessment

The 10 studies included 2 high-quality, 1 moderate-quality, and 7 low-quality studies (table 8).

Description and effectiveness of interventions

Four types of rehabilitation were investigated: balance, strength, vibration, and mixed training. Table 5 presents the data extracted from the included studies.

Balance programs included multidirectional hopping, progressive single-limb activities, wobble board exercises, and single-limb stance on different surfaces. Three studies implemented balance programs, 1 high quality and 2 low quality because of lack of blinding of assessors and inadequate allocation concealment. Anguish and Sandrey reported significant improvements in the SEBT for the progressive hop-to-stabilization and single-limb balance programs yielding an average percentage change of 4.52% and 4.89%, respectively, exceeding the corresponding MDC value of 4.48% (see table 5), indicating that these programs are effective.

Burcal et al reported significant improvements in the SEBT producing an average percentage change of 8.9%, again exceeding the corresponding MDC value of 4.48%. These authors reported that balance training alone showed an equal magnitude of change as balance training with sensory-targeted ankle rehabilitation strategies (average percentage change: 8.89%).

Linens et al reported significant improvements in the SEBT for the wobble board group, producing the largest

| Table 8 Quality assessment results |
|-----------------------------------|
| Author(S) | Adequate Randomization | Adequate Allocation Concealment | Blinding of Assessors | Intent-to-Treat Analysis | Measurement of Compliance | Van Tulder Criteria Score | High/Moderate/Low Quality |
|-----------|------------------------|---------------------------------|-----------------------|-------------------------|---------------------------|---------------------------|--------------------------|
| Anguish and Sandrey            | Y                      | Y                               | N                     | Y                       | Y                         | 7                         | High                     |
| Burcal et al                  | Y                      | Y                               | N                     | Y                       | Y                         | 5                         | Low                      |
| Cloak et al                   | U                      | N                               | N                     | Y                       | Y                         | 3                         | Low                      |
| Cruz-Diaz et al               | Y                      | Y                               | Y                     | U                       | Y                         | 7                         | High                     |
| Hall et al                    | U                      | N                               | N                     | N                       | Y                         | 5                         | Low                      |
| Hall et al                    | U                      | N                               | N                     | N                       | Y                         | 4                         | Low                      |
| Linens et al                  | U                      | U                               | N                     | Y                       | 8                         | 4                         | Low                      |
| Melam et al                   | U                      | U                               | N                     | N                       | 3                         | Low                      |
| Sierra-Guzmán et al           | Y                      | Y                               | N                     | U                       | 8                         | Moderate                  |
| Smith et al                   | Y                      | N                               | N                     | U                       | 5                         | Low                      |

Abbreviations: N, no; U, unclear; Y, yes.
average percentage change of 14.3%, exceeding the corresponding MDC value of 5.63%, indicating that this program is effective. However, this is a low-quality study because of lack of allocation concealment; therefore, these results should be interpreted with caution.

Strength training included resistance band exercises for the ankle,37,38 resistance TheraBand exercises for the hip,39 proprioceptive neuromuscular facilitation training,37 and single-leg heel raises.37

Two studies conducted a strength program; both were deemed low-quality because of inadequate allocation concealment and lack of blinding of assessors.38,39 Hall et al.40 reported that the resistance band group showed no significant improvements in the Y Balance Test, yielding a percentage change of 4.72%, which does not exceed their MDC of 7.7%, suggesting that this program is of limited effectiveness.

Smith et al.37 reported significant improvements in the SEBT for their hip strengthening group yielding an average percentage change of 12.8%, substantially exceeding the corresponding MDC value of 4.48%, suggesting that this program is effective.

One study implemented a vibration program involving single-leg heel raises and single-leg squats on a vibration platform.45 Cloak et al.45 reported significant differences in the SEBT for the WBVT group compared with the controls, producing an average percentage change of 9.64%, exceeding the corresponding MDC value of 6.4%, again suggesting that the program is effective. This study is low quality because of inadequate allocation concealment; therefore, results should be interpreted with caution.

Three studies adopted a mixed training intervention incorporating general strength and balance training,40 elastic tubing exercises and conventional physiotherapy,40 and balance and vibration training.47

One study was deemed high quality,40 1 moderate-quality,47 and 1 low quality.36 Cruz-Diaz et al.40 reported significant improvements in the SEBT for the combined training group producing an average percentage change of 5.24%, exceeding the corresponding MDC value, suggesting that this program is effective.

Melam et al.46 reported significant improvements in the SEBT for the mixed training group producing an average percentage change of 2.34%, which does not surpass the corresponding MDC value of 5.63%. Sierra-Guzmán et al.47 reported significant improvements in the combined training group and the balance only training group, producing an average percentage change of 3.5% and 5.28%, respectively, which does not meet the corresponding MDC value of 5.63%, indicating that these programs are not effective.

One study compared balance and strength training37 and reported large effect sizes for both groups, with the balance group displaying slightly greater effects than the strength training group. However, this study was low quality because of inadequate allocation concealment; therefore, results should be interpreted cautiously.

### Intervention duration

Five studies involved a 4-week intervention,35,36,39,44,46 and 5 studies implemented a 6-week intervention.37,38,40,45,47 The average percentage change of the studies that included a successful 4-week35,36,39,44 and 6-week intervention37,40,45 was 13.4% and 7.44%, respectively. Hall et al.37 did not provide data to calculate the average percentage and therefore is not comparable. These results suggest that 4 weeks of rehabilitation intervention is a sufficient duration to produce results that are clinically significant.

### Session frequency

One study completed 1 session per week,45 8 completed 3 sessions per week,35-40,44,47 and 1 completed 4 sessions per week.46

Successful interventions included a frequency of 1 session45 and 3 sessions per week,35-37,39,40,44 with an average percentage change of 9.64% and 11.49%, respectively. Hall et al.37 did not provide data to calculate the average percentage and therefore is not comparable. These results suggest that at 3 weekly sessions are sufficient to produce results that are clinically meaningful.

### Long-term effects

Burcal et al.36 reported that improvements were maintained at the 1-week follow-up displaying effect sizes of 0.49 (anterior), 0.92 (posteromedial), and 1.42 (posterolateral). Whereas Sierra-Guzmán et al.47 reported decreases from postintervention to the 6-week follow-up displaying composite effect sizes of −0.47 (vibration group) and −0.41 (nonvibration group).

### Discussion

This review aimed to determine (1) the effectiveness of rehabilitation for chronic ankle instability as measured by the SEBT and (2) the relative efficacy and the long-term effects of these rehabilitation interventions. The results suggest that rehabilitation of chronic ankle instability that includes wobble board exercises (average percentage change: 14.3%)44 and hip strengthening exercises (average percentage change: 12.8%)39 is the most effective because of a larger magnitude of change reported.

The benefits of wobble board rehabilitation for chronic ankle instability have been well-documented.68-71 Strom et al.72 investigated peroneal muscle activity and frontal plane ankle kinematics during a single-leg stance on different surfaces. They reported that the wobble board produced the largest improvements in neuromuscular abilities and ankle sensorimotor control.72 Research emphasizes that rehabilitation programs for chronic ankle instability should consider including wobble board exercises.68-71,73,74

Previous research has reported that those with chronic ankle instability rely more on the hip’s contribution during postural control tasks.75,76 Individuals with chronic ankle instability display insufficiencies in hip external rotators and gluteus medius function.77-80 Therefore, highlighting that rehabilitation programs should consider including hip strengthening exercises.

The suggested optimal frequency is 3 sessions per week (average percentage change: 11.49%). This is supported by 2 high-quality35,45 and 4 low-quality studies.36,37,39,44 The suggested optimal duration is 4 weeks (average percentage changed: 14.3%).
change: 13.4%). This result is supported by only 1 high-quality study and 3 low-quality studies. Similarly, Powden et al reported that improvements observed in individuals with chronic ankle instability after a 4-week multimodal intervention were equal to that of a 6-week intervention.

Relative efficacy of rehabilitation types

Only 1 study compared different rehabilitation types and reported that balance training was slightly more effective. However, because of this study being low quality and the lack of studies that compared different rehabilitation types, these results are not conclusive.

Long-term effects

Burcal et al reported that improvements were maintained at the 1-week follow-up displaying moderate to large effect sizes. Whereas Sierra-Guzmán et al reported decreases at the 6-week follow-up with the nonvibration group displaying better ability to maintain postintervention improvements. Because of the lack of long-term follow-up assessments, the long-term effects of the interventions are unknown.

Comparison to previous literature

This is the only review in the last 10 years that has assessed the effectiveness of different rehabilitation types and suggested optimal rehabilitation parameters. Before this review, Webster and Gribble investigated functional rehabilitation interventions for chronic ankle instability published from 1988-2008. They analyzed postural control outcome measurements in 6 studies, reporting that a 4- to 6-week intervention with 3-5 weekly sessions can improve dynamic postural control. Webster and Gribble, similar to this review, found wobble board rehabilitation effective for several stages of ankle instability. Unlike this review, Webster and Gribble assessed methodological quality of their studies using the Physiotherapy Evidence Database scale. However, the Physiotherapy Evidence Database scale has many shortcomings; it assesses the quality of reporting instead of characteristics that affect the risk of bias (which is recommended) and does not account for compliance or timing of outcomes, which are important when evaluating exercise interventions.

Study limitations

The importance of postural control is accepted for many clinical populations; however, the population of interest in this review was recreational athletes, and therefore the results may not be applicable to more general clinical groups. Second, the accumulated number of participants assessed is relatively small; including a study with a small sample size could have significantly influenced the magnitude of change between pre- and postintervention scores. Third, this review only analyzed dynamic postural control; by incorporating self-reported measures this may have provided a more in-depth functional rehabilitation program for chronic ankle instability. Lastly, because a meta-analysis was not conducted, the findings of this review can only suggest optimal rehabilitation parameters; they are not conclusive.

Despite these limitations, this review rigorously evaluated risk of bias within and across the included studies. Furthermore, this is the only review that discusses an optimal rehabilitation program for recreational athletes with chronic ankle instability, thus assisting clinicians regarding the conservative management of chronic ankle instability.

Recommendations for future research

Future trials should be adequately powered and focus on meeting the minimum standards to reduce potential threats to bias. There is a need for trials to directly compare different rehabilitation types to provide a definite conclusion regarding the relative efficacy. Future trials should include a sufficient follow-up period to determine the long-term effects of an intervention.

Clinical relevance

This review suggests the optimal rehabilitation parameters required in the management of recreational athletes with chronic ankle instability. Three weekly sessions focusing on wobble board exercises and hip strengthening for 4-6 weeks is suggested. However, the evidence is insufficient for these results to be conclusive and are only suggestions to help guide clinicians in the management of chronic ankle instability.

Conclusions

Chronic ankle instability is associated with impaired sensorimotor control, which contributes to deficits in postural control activities. A rehabilitation approach focusing on wobble board exercises and hip strengthening performed 3 times weekly for 4-6 weeks is suggested to help improve dynamic postural control in recreational athletes with chronic ankle instability, at least in the short-term. The lack of long-term follow-up studies prevents definitive conclusions, and the results are suggested as a guideline to assist clinicians in the management of recreational athletes with chronic ankle instability. The long-term effects of the interventions remain unclear and further research is required.

Corresponding author

Joseph G. McVeigh, PT, PhD, Senior Lecturer and Head of Discipline of Physiotherapy, School of Clinical Therapies, College of Medicine and Health, University College Cork, Westland Road Cork, Ireland. E-mail address: joseph.mcveigh@ucc.ie.

References

1. Beynon BD, Vacek PM, Murphy D, Alosa D, Paller D. First-time inversion ankle ligament trauma: the effects of sex, level of competition, and sport on the incidence of injury. Am J Sports Med 2005;33:1485–91.
2. Andersen TE, Floerenes TW, Arnason A, Bahr R. Video analysis of the mechanisms for ankle injuries in football. Am J Sports Med 2004;32:69–79.
3. Giza E, Fuller C, Junge A, Dvorak J. Mechanisms of foot and ankle injuries in soccer. Am J Sports Med 2003;31:550-4.

4. Valderrabano V, Hintermann B, Horisberger M, Fung TS. Ligation of posttraumatic ankle osteoarthritis. Am J Sports Med 2006;34:612-20.

5. Takao M, Uchio Y, Naito K, Fukazawa I, Ochi M. Arthrometric assessment for intra-articular disorders in residual ankle disability after sprain. Am J Sports Med 2005;33:686-92.

6. Barker HB, Beynendonk BD, Renstrom PA. Ankle injury risk factors in sports. Sports Med 1997;23:69-74.

7. Hoobtem JM, Dick R, Agel J. Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives. J Athl Train 2007;42:311-9.

8. Fong DT, Hong Y, Chan LK, Yung PS, Chan KM. A systematic review on ankle injury and ankle sprain in sports. Sports Med 2007;37:73-94.

9. Purcell SB, Schuckman BE, Docherty CL, Schrader J, Poppy P. Differences in ankle range of motion before and after 2 tape exercises. Am J Sports Med 2009;37:383-9.

10. Borowski LA, Yard EE, Fields SK, Comstock RD. The epidemiology of US high school basketball injuries, 2005-2007. Am J Sports Med 2008;36:2328-35.

11. Halasi T, Kynsburg A, Tallay A, Berkes I. Development of a new activity score for the evaluation of ankle instability. Am J Sports Med 2004;32:998-1008.

12. Freeman MA, Dean MR, Hanham IW. The etiology and prevention of functional instability of the foot. Clin Orthop Relat Res 1965;47:678-85.

13. Freeman MA, Wyke B. Articular reflexes at the ankle joint: an electromyographic study of normal and abnormal influences of ankle-joint mechanoreceptors upon reflex activity in the leg muscles. Br J Surg 1967;54:990-1001.

14. Michelson JD, Hutchins C. Mechanoreceptors in human ankle ligaments. Clin Orthop Relat Res 1995;377:219-24.

15. Tropp H, Ekstrand J, Gillquist J. Stabilometry in functional instability of the ankle and its value in predicting injury. Med Sci Sports Exerc 1984;16:64-6.

16. Anandacoomarasamy A, Bamsley L. Long term outcomes of inversion ankle injuries. Br J Sports Med 2005;39:e14... [discussion: e14].

17. Olmsted LC, Garcia CR, Hertel J, Shultz SJ. Efficacy of the star excursion balance tests in detecting reach deficits in subjects with chronic ankle instability. J Athl Train 2002;37:501.

18. Delahunt E, Bleakley CM, Bossard DS, et al. Clinical assessment of acute lateral ankle sprain injuries (ROAST): 2019 consensus statement and recommendations of the International Ankle Consortium. Br J Sports Med 2018;52:1304-10.

19. Delahunt E, Coughlan GF, Caufield B, Nightingale EJ, Lin CW, Hillel CE. Inclusion criteria when investigating insufficiencies in chronic ankle instability. Med Sci Sports Exerc 2010;42:2106-21.

20. Hertel J. Functional anatomy, pathomechanics, and pathophysiology of lateral ankle instability. J Athl Train 2002;37:364-75.

21. McKeon PO, Hertel J. Spatiotemporal postural control deficits are present in those with chronic ankle instability. BMC Musculoskelet Disord 2008;9:76.

22. Lin CF, Chen CY, Lin CW. Dynamic ankle control in athletes with ankle instability during sports maneuvers. Am J Sports Med 2011;39:2007-15.

23. Freeman MA. Instability of the foot after injuries to the lateral ligament of the ankle. Clin Orthop Relat Res 1965;47:669-77.

24. Konradsen L, Olesen S, Hansen HM. Ankle sensorimotor control and eversion strength after acute ankle inversion injuries. Am J Sports Med 1998;26:72-7.

25. Hertel J, Braham RA, Hale SA, Olmsted-Kramer LC. Simplifying the star excursion balance test: analyses of subjects with and without chronic ankle instability. J Orthop Sports Phys Ther 2006;36:131-7.

26. Plisky PJ, Rauh MJ, Kaminski TW, Woodward FB. Star excursion balance test as a predictor of lower extremity injury in high school basketball players. J Orthop Sports Phys Ther 2006;36:911-9.

27. Sarshin A, Mohammadi S, Shahradab HBP, Sedighi A. The effects of functional fatigue on dynamic postural control of badminton players. Biol Exerc 2011;7:25-34.

28. Pionnier R, Decoufou N, Barbier F, Popineau C, Simonneau-Buessinger E. A new approach of theStar Excursion Balance Test to assess dynamic postural control in people complaining from chronic ankle instability. Gait Posture 2016;45:97-102.

29. Gribble PA, Hertel J, Denegar CR, Buckley WE. The effects of fatigue and chronic ankle instability on dynamic postural control. J Athl Train 2004;39:321-9.

30. Hertel J, Olmsted-Kramer LC. Deficits in time-to-boundary measures of postural control with chronic ankle instability. Gait Posture 2007;25:33-9.

31. Hoch MC, Andreatta RD, Mullineaux DR, et al. Two-week joint mobilization intervention improves self-reported function, range of motion, and dynamic balance in those with chronic ankle instability. J Orthop Res 2012;30:1798-804.

32. Plante JF, Wikstrom EA. Differences in clinician-oriented outcomes among controls, copers, and chronic ankle instability groups. Phys Ther Sport 2013;14:221-6.

33. Martinez-Ramirez A, Lecumberri P, Gómez M, Izquierdo M. Wavelet analysis based on time-frequency information discriminates chronic ankle instability. Clin Biomech 2010;25:256-64.

34. Terada M, Harkey MS, Wells AM, PietroSimone BG, Gribble PA. The influence of ankle dorsiflexion and self-reported patient outcomes on dynamic postural control in participants with chronic ankle instability. Gait Posture 2014;40:193-7.

35. Angush B, Sandrey MA. Two 4-week balance-training programs for chronic ankle instability. J Athl Train 2018;53:662-71.

36. Burcal CJ, Trier AY, Wikstrom EA. Balance training versus balance training with STARS in patients with chronic ankle instability: a randomized controlled trial. J Sport Rehabil 2017;26:347-57.

37. Hall EA, Chemistek AK, Kingma JJ, Docherty CL. Balance- and strength-training protocols to improve chronic ankle instability deficits, part I: assessing clinical outcome measures. J Athl Train 2018;53:568-77.

38. Hall EA, Docherty CL, Simon J, Kingma JJ, Krossner JC. Strength-training protocols to improve deficits in participants with chronic ankle instability: a randomized controlled trial. J Athl Train 2015;50:36-44.

39. Smith BI, Curtis D, Docherty CL. Effects of hip strengthening on neuromuscular control, hip strength, and self-reported functional deficits in individuals with chronic ankle instability. J Sport Rehabil 2018;27:364-70.

40. Cruz-Diaz D, Lomas-Vega R, Osuna-Perez MC, Contreras FH, Martinez-Amat A. Effects of 6 weeks of balance training on chronic ankle instability in athletes: a randomized controlled trial. Int J Sports Med 2015;36:754-60.

41. Gonzales JM, Thomas AC, Burcal CJ, et al. O28 effects of a 4-week balance training and cognitive loading program in subjects with chronic ankle instability. BMJ 2017;51:A11.

42. Sefton JM, Yarar C, Hicks-Little CA, Berry JW, Cordova ML. Six weeks of balance training improves sensorimotor function in individuals with chronic ankle instability. J Orthop Sports Phys Ther 2011;41:81-9.

43. McKeon PO, Ingersoll CD, Kerrigan DC, Saliba E, Bennett BC. Hertel J. Balance training improves function and postural control in those with chronic ankle instability. Med Sci Sports Exerc 2008;40:1810-9.

44. Linens SW, Ross SE, Arnold BL. Wobble board rehabilitation for improving balance in ankles with chronic instability. Clin J Sports Med 2016;26:76-82.

45. Cloak R, Nevill AM, Clarke F, Day S, Wyon MA. Vibration training improves balance in unstable ankles. Int J Sports Med 2010;31:894-900.

46. Melam GR, Alhusaini AA, Perumal V, Buragadda S, Albarrati A, Lochab R. Effect of weight-bearing overload using elastic tubing on balance and functional performance in athletes with chronic ankle instability. Sci Sports 2018;33:E229-36.
47. Sierra-Guzman R, Jimenez-Diaz F, Ramirez C, Esteban R, Abian-Vicen J. Whole-body vibration training and balance in recreational athletes with chronic ankle instability. J Athl Train 2018;53:355-63.

48. O’Sullivan S, Portny L. Physical rehabilitation. Philadelphia: FA Davis; 2014.

49. Hale SA, Hertel J, Olmsted-Kramer LC. The effect of a 4-week comprehensive rehabilitation program on postural control and lower extremity function in individuals with chronic ankle instability. J Orthop Sports Phys Ther 2007;37:303-11.

50. Burcal CJ, Sandrey MA, Hubbard-Turner T, McKeon PO, Wikstrom EA. Predicting dynamic balance improvements following 4-weeks of balance training in chronic ankle instability patients. J Sci Med Sport 2019;22:538-43.

51. Docherty CL, Moore JH, Arnold BL. Effects of strength training on strength development and joint position sense in functionally unstable ankles. J Athl Train 1998;33:310.

52. Uh BS, Beynon BD, Helie BV, Alosa DM, Renstrom PA. The benefit of a single-leg strength training program for the muscles around the untrained ankle. Am J Sports Med 2000;28:568-73.

53. Huttson M. Sports injuries: recognition and management. New York: Oxford University Press; 1990.

54. Chromiak JA, Mulvaney DR. A review: the effects of combined strength and endurance training on strength development. J Strength Cond Res 1990;4:45-60.

55. Case W. Ankle injuries editor. In: Sanders B, ed. Sports physical therapy. Norwalk: Blackwell Scientific Publication; 1990:249-65.

56. Moritani T, deVries HA. Neural factors versus hypertrophy in the time course of muscle strength gain. Am J Phys Med 1979:58:115-30.

57. Smith BJ, Docherty CL, Simon J, Klossner J, Schrader J. Ankle strength and force sense after a progressive, 6-week strength-training program in people with functional ankle instability. J Athl Train 2012;47:282-8.

58. Moezy A, Olyaei G, Hadian M, Razi M, Faghihzadeh S. A comparative study of whole body vibration training and conventional training on knee proprioception and postural stability after anterior cruciate ligament reconstruction. Br J Sports Med 2008;42:373-85.

59. Ray J. The effects of whole body vibration versus wobble board balance exercises on dynamic postural control in recreationally active individuals with chronic ankle instability: a meta-analysis. Fresno: California State University; 2018.

60. Webster KA, Gribble PA. Functional rehabilitation interventions for chronic ankle instability: a systematic review. J Sport Rehabil 2010;19:98-114.

61. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: the PRISMA statement. PLoS Med 2009;6:e1000097.

62. Brown CN, Mynark R. Balance deficits in recreational athletes with chronic ankle instability. J Athl Train 2007;42:367-73.

63. Higgins JPT, Altman DG, Gotzsche PC, et al. The Cochrane Collaboration’s tool for assessing risk of bias in randomised trials. BMJ 2011;343:d5928.

64. Furlan AD, Pennick V, Bombardier C, van Tulder M. 2009 updated method guidelines for systematic reviews in the Cochrane Back Review Group. Spine 2009;34:1929-41.

65. Higgins JPT, Green S. Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0 [updated March 2011]. Available at www.hookbook.cochrane.org. Accessed July 27, 2021.

66. Institute of Medicine Committee on Standards for Systematic Reviews of Comparative Effectiveness Research. Chapter 4: Standards for synthesizing the body of evidence. In: Eden J, Levit L, Berg A, Morton S, eds. Finding what works in health care: standards for systematic reviews, Washington (DC): National Academies Press; 2011.

67. Munro AG, Herrington LC. Between-session reliability of the star excursion balance test. Phys Ther Sport 2010;11:128-32.

68. Wedderkopp N, Kalttof M, Holm R, Froberg K. Comparison of two intervention programmes in young female players in European handball—with and without ankle disc. Scand J Med Sci Sports 2003;13:371-5.

69. Eils E, Rosenbaum D. A multi-station proprioceptive exercise program in patients with ankle instability. Med Sci Sports Exerc 2001;33:1991-8.

70. McGuine TA, Keene JS. The effect of a balance training program on the risk of ankle sprains in high school athletes. Am J Sports Med 2006;34:1103-11.

71. Verhagen E, Van der Beek A, Twisk J, Boutier L, Bahr R, Van Mechelen W. The effect of a proprioceptive balance board training program for the prevention of ankle sprains: a prospective controlled trial. Am J Sports Med 2004;32:1385-93.

72. Strøm M, Thorborg K, Bandholm T, et al. Ankle joint control during single-legged balance using common balance training devices - implications for rehabilitation strategies. Int J Sports Phys Ther 2016;11:388.

73. van der Wees PJ, Leness AF, Hendriks EJM, Stompa DJ, Dekker J, de Bie RA. Effectiveness of exercise therapy and manual mobilisation in acute ankle sprain and functional instability: a systematic review. J Physiother 2006;52:27-37.

74. Tropp H, Asking C. Effects of ankle disc training on muscular strength and postural control. Clin Biomech (Bristol, Avon) 1988;3:88-91.

75. Doherty C, Bleakley C, Hertel J, Caulfield B, Ryan J, Delahunet E. Dynamic balance deficits in individuals with chronic ankle instability compared to ankle sprain copers 1 year after a first-time lateral ankle sprain injury. Knee Surg Sports Traumatol Arthrosc 2016;24:1086-95.

76. Rios JL, Gorges AL, dos Santos MJ. Individuals with chronic ankle instability compensate for their ankle deficits using proximal musculature to maintain reduced postural sway while kicking a ball. Hum Mov Sci 2015;43:33-44.

77. Bullock-Saxton JE. Local sensation changes and altered hip muscle function following severe ankle sprain. Phys Ther 1994;74:17-28. [discussion 28-31].

78. Friel K, McLean N, Myers C, Caceres M. Ipsilateral hip abductor weakness after inversion ankle sprain. J Athl Train 2006;41:74-8.

79. Leavey VJ, Sandrey MA, Dahmer G. Comparative effects of 6-week balance training program in patients with ankle instability. Med Sci Sports Exerc 2018;50:1968-74.

80. Norris B, Trudelle-Jackson E. Hip-and thigh-muscle activation during the star excursion balance test. J Sport Rehabil 2010;19:268-87.

81. Norris B, Trudelle-Jackson E. Hip and thigh muscle activation during the star excursion balance test. J Sport Rehabil 2010;19:268-87.

82. Moher D, Shamseer L, Clarke M, et al. Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) 2015 statement. Syst Rev 2015;4:1.

83. Taglietti M, Dela Bela LF, Dias JM, et al. Postural sway, balance confidence, and fear of falling in women with knee osteoarthritis in comparison to matched controls. PM R 2017;9:774-80.