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External Ankle Support and Ankle Biomechanics in Chronic Ankle Instability: Systematic Review and Meta-Analysis

Patrick L. Rowe, MPhysioPrac; Adam L. Bryant, PhD; Thorlene Egerton, PhD; Kade L. Paterson, PhD

Centre for Health, Exercise & Sports Medicine, University of Melbourne, Victoria, Australia

Objective: To systematically review the literature to determine whether external ankle supports influence ankle biomechanics in participants with chronic ankle instability (CAI) during sport-related tasks.

Data Sources: A literature search of MEDLINE, SPORTDiscus, and CINAHL databases was conducted in November 2021.

Study Selection: Included studies were randomized crossover or parallel-group controlled trials in which researchers assessed ankle biomechanics during landing, running, or change of direction in participants with CAI using external ankle supports compared with no support.

Data Extraction: Two authors independently identified studies, extracted data, and assessed risk of bias (Cochrane risk-of-bias tool version 2) and quality of evidence (Grading of Recommendations Assessment, Development and Evaluation). Random-effects meta-analysis was used to compare between-groups mean differences with 95% CIs. Grading of Recommendations Assessment, Development and Evaluation recommendations were used to determine the certainty of findings.

Data Synthesis: A total of 13 studies of low to moderate risk of bias were included. During landing, very low-grade evidence indicated external ankle supports reduce frontal-plane excursion (mean difference [95% CI] = −1.83° [−2.97°, −0.69°], $P = .002$), plantar-flexion angle at initial contact (−3.86° [−6.18°, −1.54°], $P = .001$), and sagittal-plane excursion (−3.45° [−5.00°, −1.90°], $P < .001$) but not inversion angle at initial contact (−1.00° [−3.59°, 1.59°], $P = .45$). During running, very low- to low-grade evidence indicated external ankle supports reduce sagittal-plane excursion (−5.21° [−8.59°, −1.83°], $P = .003$) but not inversion angle at initial contact (0.32° [−2.11°, 1.47°], $P = .73$), frontal-plane excursion (−1.31° [−3.24°, 0.63°], $P = .19$), or plantar-flexion angle at initial contact (−0.12° [−3.54°, 3.29°], $P = .94$). Studies investigating changes of direction were insufficient.

Conclusions: Very low-grade evidence indicated external ankle supports reduce frontal-plane excursion but not inversion angle at initial contact in participants with CAI during landing. Limiting frontal-plane excursion may reduce ankle-sprain risk. Frontal-plane ankle kinematics were not influenced by external ankle supports during running. Sagittal-plane reductions were observed with external ankle supports during landing and running with low to very low certainty, but their influence on ankle-sprain risk is undetermined.

Key Words: ankle sprain, taping, bracing, kinematics, kinetics, landing, running, change of direction

Key Points

- Very low-grade evidence indicated that external ankle supports reduce ankle frontal-plane kinematics during landing but not running for individuals with chronic ankle instability.
- Reducing ankle frontal-plane excursion with external ankle supports during landing tasks may play an important role in mitigating ankle-sprain risk.
- Very low- to low-grade evidence indicated external ankle supports reduce ankle sagittal-plane kinematics, but it is undetermined if this influences ankle-sprain risk.

Ankle sprains account for a large proportion of musculoskeletal injuries reported in active and sporting populations.[1] They commonly result from an awkward landing, pivoting, or player contact mechanism, resulting in high ankle-supination velocities and compromising the lateral ankle-ligament complex.[2] The incidence rates of ankle sprains are substantially greater in children (2.85 per 1000 exposures), adolescents (1.94 per 1000 exposures), females (13.6 per 1000 exposures), and indoor court sports (7.0 per 1000 exposures).[3] Ankle sprains are often underestimated as innocuous injuries with minimal complications and long-term implications.[4] However, up to half of individuals report chronic ankle instability (CAI) characterized by persistent residual symptoms, perception of their ankle joint "giving way," and disability >12 months after their initial sprain.[5,6] Worryingly, the prevalence of CAI is as high as 70% to 80% in multidirectional sports, including basketball, netball, and soccer.[7]

The characteristics of CAI often vary among individuals because of its heterogeneous nature, but altered biomechanics is one of the most common features. Researchers have shown that individuals with CAI typically exhibit a more externally rotated shank, less dorsiflexed ankle, and more inverted rearfoot during gait and landing.[8,9] During cutting maneuvers, they demonstrate a more internally rotated ankle.[10] During landing tasks, individuals with CAI have a less plantar-flexed ankle at initial contact and reduced sagittal-plane excursion, leading to higher peak vertical ground reaction force (vGRF).[11] These biomechanical alterations and compensatory mechanisms may explain the heightened risk of sustaining further sprains.[8,10]

External ankle supports such as taping and bracing are commonly used by individuals with CAI to improve stability and reduce the risk of further sprains. Researchers have suggested that these supports may reduce ankle-sprain risk by as much as 62%.[12–14] External ankle supports are thought to reduce recurrent sprains by providing mechanical support, increasing proprioception, and enhancing psychological confidence.[15–18] In healthy individuals, they have been shown in several but not all studies to reduce frontal-plane motion at the ankle joint.[19] For individuals with CAI who already demonstrate a greater lateral shifting of force at the ankle-foot complex, a reduction in frontal-plane excursion when using external ankle supports may be important in reducing the risk of subsequent sprains.[8,9] In contrast, potentially undesirable biomechanical alterations have also been observed when using external ankle supports. These include a reduced plantar-flexion angle at initial contact and peak dorsiflexion angle, leading to a decreased sagittal-plane excursion and time to peak force.[19,20] This may have implications for proximal compensatory patterns, particularly in individuals with CAI who have sagittal-plane restriction even without external ankle supports.[8,9,21]

Currently a gap exists in the systematic evidence pertaining to the effect of external ankle supports in individuals with CAI during sport-related tasks. In a recent systematic review, Megalaa et al[22] examined the influence of external ankle supports on lower limb biomechanics during weight-bearing tasks. However, the authors pooled randomized and nonrandomized studies and included participants with and those without a history of ankle sprain in their meta-analysis.[22] In another systematic review, Migel and Wikstrom[23] investigated the biomechanical effect of external ankle supports in individuals with CAI. They included 3 low-quality studies and found that external ankle supports may reduce plantar-flexion and inversion angles during walking.[23] Since this review was published, several researchers have investigated the biomechanical effects of external ankle supports in individuals with CAI during sport-related tasks, including running, landing, and change of direction.[22] Investigating biomechanical effects of external ankle supports during these tasks will be of greater relevance to athletes prone to CAI, given that most ankle sprains occur during these sporting maneuvers rather than during walking.

The overall aim of this systematic review was to determine whether external ankle supports influence frontal- and sagittal-plane biomechanics during landing, running, and change-of-direction tasks.

METHODS

Overview

We performed this systematic review using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines in accordance with the Implementing PRISMA in Exercise, Rehabilitation, Sport Medicine and Sports Science protocol.[24,25] The study was registered with the International Prospective Register of Systematic Reviews on August 20, 2020 (CRD42020202199). After preliminary searches, we amended the inclusion criteria and risk-of-bias assessment from the original International Prospective Register of Systematic Reviews registration. Amendments were the inclusion of randomized crossover and parallel-group controlled trials that included running and change-of-direction tasks in addition to the landing tasks in the original plan. This was done to provide more comprehensive findings relevant to athletes with CAI who use external ankle supports when participating in multidirectional sports. In addition, the Cochrane risk-of-bias tool version 2 (RoB 2) was used instead of the Physiotherapy Evidence Database scale to assess risk of bias of crossover studies.

Research Question

In accordance with the Cochrane handbook,[26] the research question was developed using the PICOT model to determine the effectiveness of an intervention.[27] The format of the PICOT model is as follows:

Population: individuals with CAI
Intervention: external ankle supports (taping or bracing)
Comparison: no external ankle support
Outcome: ankle frontal- or sagittal-plane biomechanics
Task: running, landing, or change-of-direction

Study Identification

We conducted an electronic database search on November 15, 2021, using MEDLINE, SPORTDiscus, and CINAHL databases to identify peer-reviewed studies. Studies were limited to those written in the English language with no restriction on publication date. Search terms included free-text terms (*ankle sprain* or *ankle instability* or *CAI* or *unstable ankle*) and (*biomechanic** or *kinematic** or *kinetic**) and (*tap** or *brac** or *strap** or *elastic* or *kinesio** or *prophylactic* or *external support*) and (*jump** or *land** or *run** or *cut** or *agility* or *change of direction*). The search strategy across all databases and results is provided in Supplemental Table 1. Reference lists of included studies and relevant systematic reviews were reviewed to capture additional studies. Citations were downloaded to EndNote X9.2 (Clarivate) software. All titles and abstracts captured by the search strategy were independently assessed by 2 authors (P.L.R. and K.L.P). The full text of studies approved by at least 1 reviewer was then evaluated independently by both reviewers against eligibility criteria. A third reviewer (A.L.B.) was consulted if consensus was not reached.

Eligibility Criteria

We included studies in our review if (1) they were peer-reviewed randomized crossover or parallel-group controlled trials; (2) participants had a chronically unstable ankle (ie, a history of recurrent ankle sprains, self-reported instability, or both); (3) the intervention group implemented external ankle supports (taping or bracing) and the control group did not; (4) ankle sagittal-plane kinematics, frontal-plane kinematics, kinetics, or a combination were measured; and (5) a running, landing, or change-of-direction task was investigated. Studies were excluded if they (1) did not clearly define or include participants with CAI; (2) did not provide sufficient data to be included in the review; (3) were written in languages other than English; or (4) did not have full text available. Gribble et al[6] described selection criteria for participants with CAI, which include the following: (1) a history of a significant ankle sprain resulting in inflammatory symptoms and disability; (2) a history of $\geq$2 episodes of the ankle joint giving way in the last 6 months, self-reported ankle instability using the Cumberland Ankle Instability Tool (CAIT) (cutoff score of $\leq$24), or recurrent ankle sprains ($\geq$2); and (3) self-reported ankle disability using the Foot and Ankle Ability Measure (FAAM) Activities of Daily Living ($\leq$90%) and Sport (FAAM-S) subscales ($\leq$80%). However, we aimed to include studies published before the consensus statement to increase the data available for pooled analyses, so studies in which researchers used more generic inclusion criteria for participants with CAI (recurrent ankle sprains, ankle instability, or both) were not excluded.

Methodological Quality

We used the RoB 2 for crossover studies to assess the methodological quality of the included studies. The RoB 2 is widely used and appropriate for systematic reviews that include crossover studies to determine risk of bias.[28] It does not assess blinding protocols for crossover studies, given that participants will undertake both conditions and therefore cannot be blinded. Two reviewers (P.L.R. and K.L.P.) independently assessed the included studies using 6 domains (randomization process, period and carryover effects, deviations from intended interventions, missing outcome data, measurement of the outcome, and selection of the reported result). Signaling questions were answered within each domain (*yes*, *probably yes*, *probably no*, and *no information*) to generate a final result for the risk of bias using a 3-tier grading system (*low risk*, *some concerns*, and *high risk*). The overall risk of bias for each study was determined from the results of all domains. If a study scored *low risk* on all domains, it was deemed to have low risk of bias. Studies with $\geq$1 domain graded as *some concerns* but no domains graded as *high risk* were considered to have an overall unclear risk of bias. Studies with 1 domain graded as *high risk* or several domains graded as *some concerns* were deemed as having a high risk of bias. Discrepancies between the results of the RoB 2 domains and the overall risk of bias between authors were discussed to reach consensus. A third author (A.L.B.) determined the final rating if no agreement was reached.

Quality of Evidence

The quality of the evidence and level of certainty were assessed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) framework.[29] Two reviewers (P.L.R. and K.L.P.) independently evaluated the quality of evidence of each outcome measure using GRADEpro software (McMaster University and Evidence Prime; https://www.gradepro.org) and presented a summary-of-findings table. Each outcome measure was considered high quality because of the inclusion of randomized controlled trials. However, the quality of evidence was then downgraded based on each certainty assessment, including inconsistency of study results, indirectness of evidence, imprecision of findings, and the likelihood of publication bias. For each assessment measure, evidence was downgraded by 1 or 2 levels. A final rating for each outcome measure was defined as a *high*, *moderate*, *low*, or *very low level of certainty.*

Data Extraction

Two authors (P.L.R. and K.L.P.) independently extracted the data from all included studies. Data of interest included study (authors, date of publication, and crossover or parallel-group design), participant (age, height, mass, and patient-reported outcome measures), and intervention characteristics (type of external ankle support, application, task performed, and description of control group). Outcome data included ankle kinematics (angle at initial contact, excursion, and peak angle) and kinetics (angular velocity, moment, vGRF, time to peak force, and loading rate) in the sagittal and frontal planes from landing, running, and change-of-direction tasks. Data from intervention (taping or bracing) and control (barefoot or shod) group conditions were extracted. Types of external ankle supports were grouped into semirigid bracing, soft bracing, nonelastic taping, and elastic taping. For nonelastic and elastic taping, taping techniques were included only if they directly crossed the ankle joint. Authors were contacted if study data were not available within the full text. For example, if only figures displaying statistical parametric mapping of gait cycles were presented in the study, raw data for all conditions were requested.

Data Analysis

Comparisons between external ankle supports and controls were conducted using mean differences and 95% CIs with an α level of .05. To answer the primary aim, we compared external ankle supports and controls on frontal-plane biomechanics during landing. Similar analyses were carried out for secondary aims, comparing external ankle supports and controls on frontal-plane biomechanics during running and change of direction and on sagittal-plane biomechanics during landing, running, and change of direction. As per the Cochrane handbook,[26] studies with multiple conditions were included in the same meta-analysis, with control group sample sizes being divided evenly across conditions. A random-effects meta-analysis was undertaken to compare between-groups differences in the mean values of $\geq$2 studies. Statistical heterogeneity was assessed using the I^2 value, with a higher value representing a greater likelihood of methodological inconsistencies between studies.[26] Sample sizes were used to determine the weighting of studies within each analysis. A narrative synthesis of the available data was used if insufficient data were available. The GRADE recommendations were used to determine the certainty of the findings from meta-analyses of each outcome. Data extracted from studies were entered into ReviewManager 5.3 (Cochrane) for analysis.

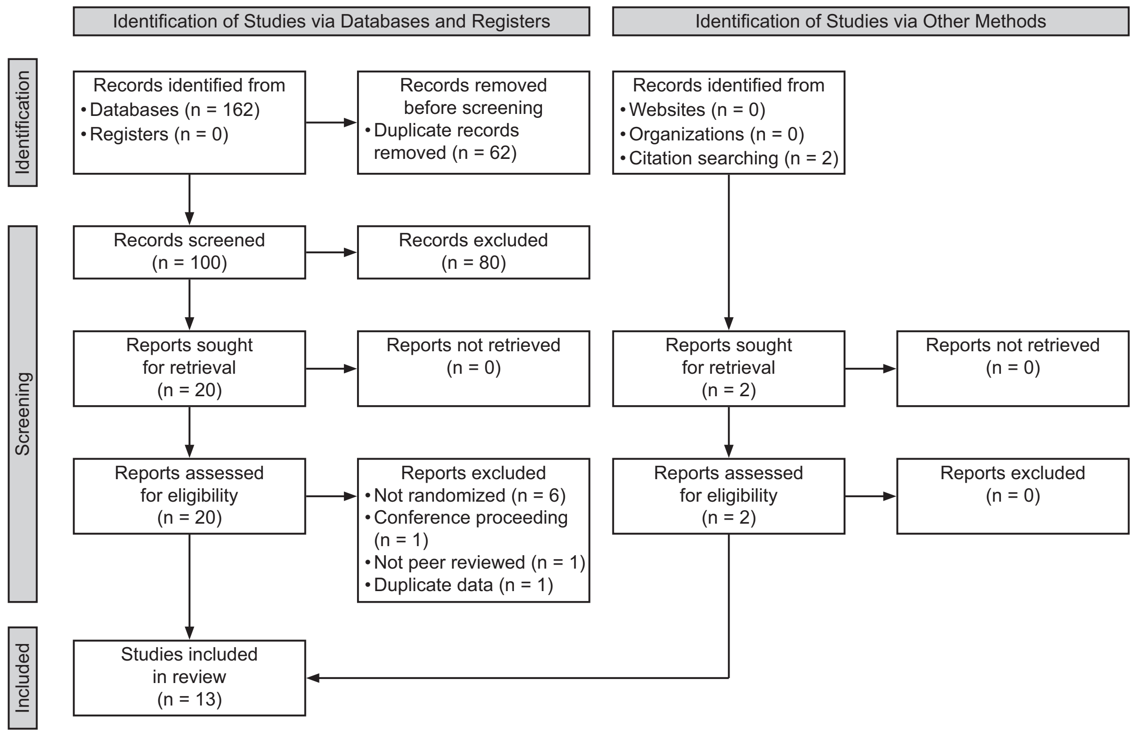


Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 flowchart of included and excluded studies.[24]

RESULTS

Identification of Studies

We identified 162 studies from our database search. After the removal of duplicates, 100 studies remained. After title and abstract screening, the full texts of 20 studies were assessed. Nine studies were excluded: 6 did not undertake randomization,[30–35] 1 was a conference proceeding, 1 was not peer reviewed,[36] and 1 had duplicate data with another included study.[37] Two additional studies were discovered during reference checking. Therefore, 13 studies were included in this systematic review.[38–50] The PRISMA flowchart is presented in Figure 1.

Risk of Bias

Using the RoB 2 tool, 5 studies were considered to have a low risk of bias,[39,45–48] 6 studies had some concerns for risk of bias,[38,41–44,50] and 2 had a high risk of bias.[40,49] A breakdown of risk-of-bias domains for each study is shown in Figure 2A. All studies had a low risk of bias for domains of deviations from the intended interventions and selection of the reported result. More than 80% of studies had a low risk of bias for randomization process and missing outcome data. However, >50% of studies had uncertainty or high risk of bias arising from period and carryover effects; several studies did not specify or completed very short washout periods, which may result in carryover effects between conditions. The weightings for each domain are shown in Figure 2B.

Participant Characteristics

Participant characteristics for all studies are included in Supplemental Table 2. A total of 248 participants with CAI (131 men and 117 women) were included in the systematic review. The mean age of participants ranged from 22.0 to 30.9 years (median of study means = 23.7 years), mean height ranged from 169.0 cm to 176.4 cm (median of study means = 173.0 cm), and mean body mass ranged from 66.3 kg to 73.5 kg (median of study means = 70.2 kg). Two studies did not provide their participants' height and weight.[42,43] Eleven studies included physically active participants,[38–48] including 9 reporting duration of physical activity (eg, >1.5 h/wk)[38–46] and 4 reporting activity level (student or competitive athlete).[45–48] All studies required participants to have sustained multiple ankle sprains, have perceived instability or giving way of their ankle joint, or both.[38–50] Five studies used the CAIT for their participants with CAI.[42–45,49] A CAIT score of ≤24 is the cutoff score for CAI.[6] However, only 3 studies reported CAIT scores, ranging between 17.1 and 19.7 (median of study means = 17.2).[44,45,49] Mechanical stability was considered by authors of 2 studies.[44,45] Several studies also measured ankle disability. One study each used the FAAM-S (mean score = 75.8%)[39]; Foot and Ankle Disability Index (FADI; mean score = 88.2%)[40]; FADI-Sport (mean score = 69.0%)[40]; Ankle Joint Functional Assessment Tool (mean score = 14.9)[50]; and Foot and Ankle Outcome Score subscales of quality of life (mean score = 71.5%), negative symptoms (mean score = 78.3%), sports participation (mean score = 87.5%), pain (mean score = 90.5%) and activities of daily living (mean score = 97.5%).[38] The FAAM-S (<80%), FADI (<90%), FADI-Sport (<80%), Ankle Joint Functional Assessment Tool (<22), and Foot and Ankle Outcome Score (75% in ≥3 categories) are all reliable measures of ankle disability.[6,51,52] Variation in ankle disability measures made it difficult to compare between-studies differences and may have contributed to greater statistical heterogeneity. Of the 13 studies captured, only 5 described[42–45,49] the selection criteria for participants with CAI endorsed by the International Ankle Consortium.[6]

Figure 2. A, Assessment of risk of bias of included studies, and B, bias weightings for each domain using the Cochrane risk-of-bias tool. Abbreviations: D1, risk of bias arising from the randomization process; D1b, risk of bias arising from period and carryover effects; D2, risk of bias due to deviations from the intended intervention; D3, risk of bias due to missing outcome data; D4, risk of bias in measurement of the outcome; D5, risk of bias in selection of the reported result.

Types of External Ankle Support

Several types of external ankle supports were used within each outcome and are presented in the Table and Supplemental Table 2. Six studies used nonelastic taping,[39–43,48] and 4 studies each used semirigid bracing,[38,41,44,50] soft bracing,[44,45,49,50] and elastic taping.[45–48] The different styles of nonelastic taping included high dye (2 proximal/distal anchors, 3 vertical and horizontal weaving stirrups, and 2 heel locks),[42,43] closed basketweave (prewrap, 2 proximal/distal anchors, 3 vertical and horizontal weaving stirrups),[41,48] traditional (prewrap, base strips, 3 stirrups, 2 heel locks, and 2 figures-of-eight),[39] and lateral stability (2 figures-of-six and 1 medial heel lock)[40] techniques. Elastic taping was applied in horizontal I strip, vertical Y strip, and horizontal Y strips across the ankle-foot complex to restrict rearfoot inversion and internal rotation in 3 studies[46–48] and in vertical strips extending from the foot across the gastrocnemius, tibialis anterior, and peroneus longus muscles to attenuate ankle-joint loading in 1 study.[45] The control groups completed the tasks in footwear in 9 studies[38,39,44–50] and barefoot in the remaining 4 studies.[40–43]

Tasks

Tasks performed in all studies are presented in the Table and Supplemental Table 2. Participants in 7 studies completed landing tasks.[38,40,41,45–47,50] In 6 of these studies, participants completed a single-legged drop landing task from 20-cm,[38] 30-cm,[45–47] and 60-cm heights.[41,50] Participants in 1 study completed a single-legged drop-forward jump-landing task over a 30-cm hurdle and a distance of 40% of the athlete's height, respectively.[40] In 5 studies, participants completed running tasks at set speeds of 2.68 m/s,[39] 2.78 m/s,[49] 3.30 m/s,[42,43] and maximum speed.[48] Participants in 2 studies completed change-of-direction tasks at 3.50 m/s[44] and maximum speed.[48]

Frontal-Plane Biomechanics During Landing

Five studies[38,40,41,47,50] investigated 6 different ankle frontal-plane biomechanical variables during landing and are presented in the Table. Regarding frontal-plane kinematics, meta-analysis of 2 studies[38,40] found that external ankle supports do not reduce inversion angle at initial contact (mean difference = −1.00° [95% CI = −3.59°, 1.59°], I^2 = 0%, Z = 0.86, P = .45; Figure 3A). The certainty of evidence was rated as very low, with confidence downgraded because of risk of bias and imprecision (Figure 4). Meta-analysis of 5 studies[38,40,41,47,50] found that external ankle supports reduce frontal-plane excursion (−1.83° [95% CI = −2.97°, −0.69°], I^2 = 0%, Z = 3.15, P = .002; Figure 3B). The quality of evidence was rated as very low, with confidence downgraded because of risk of bias, indirectness, and imprecision (Figure 4). Regarding frontal-plane kinetics, limited studies[41,46,47,50] suggested that external ankle supports may reduce eversion velocity but not inversion velocity, eversion moment, or inversion moment (Supplemental Figure 1).

Table. Characteristics of Included Studies

Task Performed	Outcome Measure	External Ankle Support	References
Landing	Frontal-plane biomechanics	Semirigid bracing: 4 studies[38,40,41,50]	Agres et al,[38] 2019
	Initial contact angle: 2 studies[38,40]	Nonelastic taping: 2 studies[40,41]	De Ridder et al,[40] 2015
	Excursion: 5 studies[38,40,41,47,50]	Soft bracing: 1 study[50]	McKelle Ulm et al,[41] 2015
	Velocity: 1 study[46]	Elastic taping: 2 studies[46,47]	Sarvestan et al,[46] 2021
			Sarvestan et al,[47] 2020
			Zhang et al,[50] 2012
	Sagittal-plane biomechanics	Semirigid bracing: 3 studies[38,41,50]	Agres et al,[38] 2019
	Initial contact angle: 3 studies[38,40,50]	Nonelastic taping: 2 studies[40,41]	De Ridder et al,[40] 2015
	Excursion: 5 studies[38,40,41,47,50]	Soft bracing: 1 study[50]	McKelle Ulm et al,[41] 2015
	Velocity: 1 study[46]	Elastic taping: 2 studies[46,47]	Sarvestan et al,[46] 2021
			Sarvestan et al,[47] 2020
			Zhang et al,[50] 2012
Running	Frontal-plane biomechanics	Nonelastic taping: 3 studies[39,42,43]	Chinn et al,[39] 2014
	Initial contact angle: 3 studies[39,43,49]	Soft bracing: 1 study[49]	Deltour et al,[42] 2021
	Excursion: 4 studies[39,42,43,49]		Deschamps et al,[43] 2016
	Peak angle: 1 study[49]		Stotz et al,[49] 2021
	Sagittal-plane biomechanics	Nonelastic taping: 4 studies[39,42,43,48]	Chinn et al,[39] 2014
	Initial contact angle: 2 studies[39,43]	Soft bracing: 1 study[49]	Deltour et al,[42] 2021
	Excursion: 5 studies[39,42,43,48,49]	Elastic taping: 1 study[48]	Deschamps et al,[43] 2016
			Sarvestan et al,[48] 2019
			Stotz et al,[49] 2021
Change of direction	Frontal-plane biomechanics	Semirigid bracing: 1 study[44]	Fuerst et al,[44] 2021
	Initial contact angle: 1 study[44]	Soft bracing: 1 study[44]	
	Excursion: 1 study[44]		
	Sagittal-plane biomechanics	Nonelastic taping: 1 study[48]	Sarvestan et al,[48] 2019
	Excursion: 1 study[48]	Elastic taping: 1 study[48]	

Frontal-Plane Biomechanics During Running

Four studies investigated 3 different ankle frontal-plane biomechanical variables during running and are presented in the Table.[39,42,43,49] Meta-analysis of 3 studies[39,43,49] found that external ankle supports do not reduce inversion angle at initial contact (−0.32° [95% CI = −2.11°, 1.47°], $I^2 = 0\%$, $Z = 0.35$, $P = .73$; Figure 5A). The quality of evidence was rated as very low, with confidence downgraded because of risk of bias and imprecision (Figure 4). For frontal-plane excursion, meta-analysis of 4 studies[39,42,43,49] found no difference between external ankle supports and controls (−1.31° [95% CI, −3.24°, 0.63°],

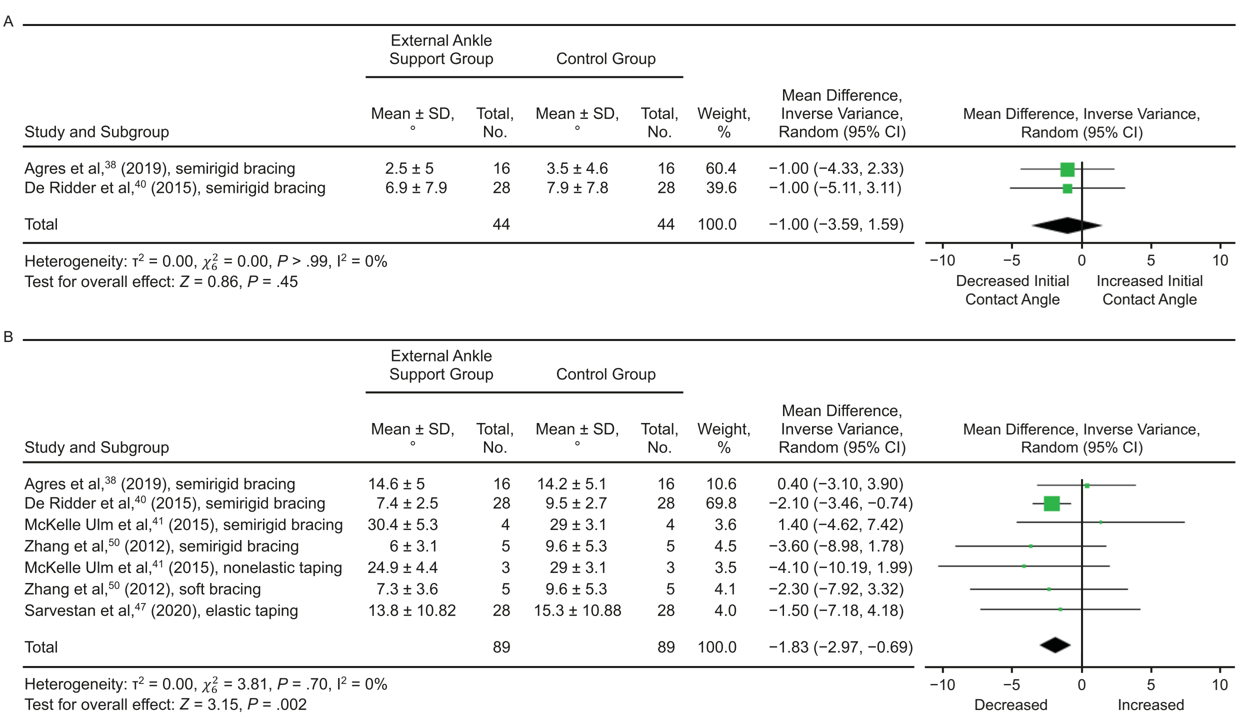


Figure 3. Meta-analysis forest plots showing the effects of external ankle support on A, inversion angle at initial contact, and B, frontal-plane excursion during landing. Abbreviations: ET, elastic taping; NET, nonelastic taping; SB, soft bracing; SRB, semirigid bracing.

	Certainty Assessment							No. of Patients			
Outcome	No. of Studies	Study Design	Risk of Bias	Inconsistency	Indirectness	Imprecision	Other Considerations	External Ankle Support	No External Ankle Support	Absolute Mean Difference (95% CI)	Certainty
Inversion angle at initial contact											
Landing	2	Crossover	Serious[a]	Not serious	Not serious	Very serious[b,c]	None	44	44	−1.00° (−3.59°, 1.59°)	⊕◯◯◯ Very low
Running	3	Crossover	Very serious[d]	Not serious	Not serious	Very serious[b,c]	None	36	36	−0.32° (−2.11°, 1.47°)	⊕◯◯◯ Very low
Frontal-plane excursion											
Landing	5	Crossover	Serious[a]	Not serious	Serious[e]	Very serious[b,c]	None	89	89	−1.83° (−2.97°, −0.67°)	⊕◯◯◯ Very low
Running	4	Crossover	Very serious[d]	Serious[f,g]	Not serious	Very serious[b,c]	None	51	51	−1.31° (−3.24°, 0.63°)	⊕◯◯◯ Very low
Plantar-flexion angle at initial contact											
Landing	3	Crossover	Serious[a]	Not serious	Not serious	Very serious[b,c]	Strong association	54	54	−3.86° (−6.18°, −1.54°)	⊕⊕◯◯ Low
Running	3	Crossover	Very serious[d]	Very serious[g,h,i,j]	Not serious	Very serious[b,c]	None	36	36	−0.12° (−3.54°, 3.29°)	⊕◯◯◯ Very low
Sagittal-plane excursion											
Landing	5	Crossover	Serious[a]	Not serious	Serious[e]	Very serious[b,c]	Strong association	89	89	−3.45° (−5.00°, −1.90°)	⊕◯◯◯ Very low
Running	5	Crossover	Very serious[d]	Serious[f,i]	Serious[e]	Very serious[b,c]	Strong association	76	76	−5.21° (−8.59°, −1.83°)	⊕◯◯◯ Very low

Figure 4. Grading of Recommendations Assessment, Development and Evaluation (GRADE) for meta-analyses of outcome measures. [a] Carryover effects likely due to crossover protocols. [b] Small sample size. [c] Wide CIs. [d] High risk of bias. [e] Variability between interventions. [f] Significant variation in effect sizes. [g] Large I^2 value. [h] Confidence intervals do not overlap. [i] Inconsistent direction of effect. [j] Heterogeneity statistically significant ($P < .05$).

$I^2 = 51\%$, Z = 1.32, $P = .19$; Figure 5B). The quality of evidence was rated as very low, with confidence downgraded because of risk of bias, inconsistency, and imprecision (Figure 4). For peak inversion angle, 1 study[41] found no difference between external ankle supports and controls (Supplemental Figure 2).

Frontal-Plane Biomechanics During Change of Direction

One study investigated 4 different ankle frontal-plane biomechanical variables during change of direction.[44] This study found no difference between external ankle supports and controls in inversion angle at initial contact, peak inversion angle, angular moment, or velocity (Supplemental Figure 3). Given the limited evidence, it is uncertain whether external ankle supports influence frontal-plane biomechanics during change-of-direction tasks.

Sagittal-Plane Biomechanics During Landing

Six studies investigated 7 different ankle sagittal-plane biomechanical variables during landing and are presented in the Table.[38,40,41,47,48,50] Meta-analysis of 3 studies[38,40,50] found that external ankle supports reduce plantar-flexion angle at initial contact (−3.86° [95% CI = −6.18°, −1.54°], $I^2 = 0\%$, Z = 3.26, $P = .001$; Figure 6A). The quality of evidence was rated as low, with confidence downgraded because of risk of bias and imprecision (Figure 4). In addition, meta-analysis of 5 studies[38,40,41,47,50] found that external ankle supports reduce sagittal-plane excursion compared with controls (−3.45° [95% CI = −5.00°, −1.90°], $I^2 = 0\%$, Z = 4.37, $P < .001$; Figure 6B). The quality of evidence was rated as very low, with confidence downgraded because of risk of bias, indirectness, and imprecision (Figure 4). Dorsiflexion velocity during landing was less with external ankle supports (−34.30°/s [95% CI = −54.27°/s, −14.32°/s], $I^2 = 0\%$, Z = 3.37, $P < .001$), but no difference was found for plantar-flexion moment (−0.01 N·m/kg [95% CI = −0.08, 0.05 N·m/kg], $I^2 = 0\%$, Z = 0.42, $P = .67$), peak vGRF (0.05% of body weight [95% CI = −0.09, 0.19% of body weight], $I^2 = 0\%$, Z = 0.68, $P = .49$), time to peak force (−4.31 milliseconds [95% CI = −10.68, 2.06 milliseconds], $I^2 = 0\%$, Z = 1.33, $P = .18$), or loading rate (0.23 N/ms [95% CI = −1.52, 1.99 N/ms], $I^2 = 4\%$, Z = 0.26, $P = .79$; Supplemental Figure 4).

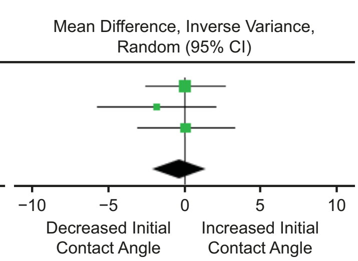
Sagittal-Plane Biomechanics During Running

Five studies investigated 3 different ankle sagittal-plane biomechanical variables during running and are presented in the Table.[39,42,43,48,49] Meta-analysis of 3 studies[39,43,49] found that external ankle supports do not reduce plantar-flexion angle at initial contact (−0.12° [95% CI = −3.54°, 3.29°], $I^2 = 85\%$, Z = 0.07, $P = .94$; Figure 7A). The quality of evidence was rated as very low, with confidence downgraded because of risk of bias, inconsistency, and imprecision (Figure 4). In contrast, meta-analysis of 5 studies[39,42,43,48,49] found that external ankle supports reduce sagittal-plane excursion compared with controls (−5.21° [95% CI = −8.59°, −1.83°], $I^2 = 17\%$, Z = 3.02, $P = .003$; Figure 7B). The quality of evidence was rated as very low, with confidence downgraded because of risk of bias,

A

Study and Subgroup	External Ankle Support Group Mean ± SD, °	External Ankle Support Group Total, No.	Control Group Mean ± SD, °	Control Group Total, No.	Weight, %	Mean Difference, Inverse Variance, Random (95% CI)
Chinn et al,[39] (2014), nonelastic taping	7.45 ± 2.65	7	7.38 ± 2.33	7	46.9	0.07 (−2.54, 2.68)
Deschamps et al,[43] (2016), nonelastic taping	9.4 ± 6	15	11.2 ± 4.7	15	21.5	−1.80 (−5.66, 2.06)
Stotz et al,[49] (2021), soft bracing	16.02 ± 4.05	14	15.91 ± 4.53	14	31.6	0.11 (−3.07, 3.29)
Total		36		36	100.0	−0.32 (−2.11, 1.47)

Heterogeneity: $\tau^2 = 0.00$, $\chi^2_2 = 0.72$, $P = .70$, $I^2 = 0\%$
Test for overall effect: $Z = 0.35$, $P = .73$



B

Study and Subgroup	External Ankle Support Group Mean ± SD, °	External Ankle Support Group Total, No.	Control Group Mean ± SD, °	Control Group Total, No.	Weight, %	Mean Difference, Inverse Variance, Random (95% CI)
Chinn et al,[39] (2014), nonelastic taping	10.97 ± 3.61	7	16.1 ± 5.47	7	12.2	−5.13 (−9.99, −0.27)
Deltour et al,[42] (2021), nonelastic taping	9.8 ± 2.2	15	9.5 ± 1.9	15	40.7	0.30 (−1.17, 1.77)
Deschamps et al,[43] (2016), nonelastic taping	11.2 ± 5.8	15	12.8 ± 6.4	15	14.3	−1.60 (−5.97, 2.77)
Stotz et al,[49] (2021), soft bracing	10.75 ± 2.5	14	12.5 ± 3.14	14	32.7	−1.75 (−3.85, 0.35)
Total		51		51	100.0	−1.31 (−3.24, 0.63)

Heterogeneity: $\tau^2 = 1.83$, $\chi^2_3 = 6.09$, $P = .11$, $I^2 = 51\%$
Test for overall effect: $Z = 1.32$, $P = .19$

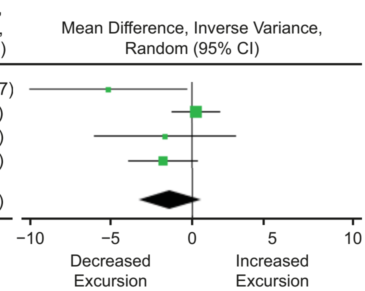


Figure 5. Meta-analysis forest plots showing the effects of external ankle support on A, inversion angle at initial contact, and B, frontal-plane excursion during running. Abbreviations: NET, nonelastic taping; SB, soft bracing.

inconsistency, indirectness, and imprecision (Figure 4). For peak dorsiflexion angle, 1 study[49] found no difference between external ankle supports and controls (Supplemental Figure 5).

Sagittal-Plane Biomechanics During Change of Direction

One study investigated 1 ankle sagittal-plane biomechanical variable during change of direction.[48] The study found no difference between external ankle supports and controls in sagittal-plane excursion (Supplemental Figure 6). The limited evidence makes it uncertain whether external ankle supports influence sagittal-plane biomechanics during change-of-direction tasks.

DISCUSSION

We systematically reviewed the literature to understand whether external ankle supports influence frontal- and sagittal-plane biomechanics in individuals with CAI when performing sport-related tasks associated with ankle sprains. Our meta-analyses showed very low-certainty evidence that external ankle supports reduce frontal-plane ankle excursion but not ankle inversion angle at initial contact compared with no external ankle supports during landing. During running and change of direction, external ankle supports did not affect frontal-plane kinematics. In the sagittal plane, we found low- to very low-certainty evidence that external ankle supports reduce plantar-flexion angle at initial contact, sagittal-plane excursion, and dorsiflexion velocity during landing. Sagittal-plane excursion was also reduced with external ankle supports during running, but no effect was found for sagittal-plane variables during change of direction. The findings of reduced frontal- and sagittal-plane excursion, sagittal-plane angle at initial contact, and sagittal-plane velocity during landing tasks suggest a mechanism through which external ankle supports may reduce biomechanical factors known to increase the risk of a future ankle sprain for individuals with CAI. However, included studies were of lower quality with small sample sizes and large heterogeneity, which affected the level of certainty of the effect estimates.

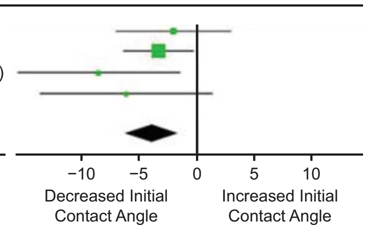
In this review, we found that external ankle supports do not affect ankle inversion angle at initial contact for individuals with CAI during landing and running tasks. This finding is consistent with the findings of previous researchers investigating external ankle supports in healthy individuals.[19,53] It is well established that individuals with CAI have a more inverted ankle at initial contact compared with healthy individuals.[8,11] Outcomes of our meta-analyses showed that external ankle supports do not reduce inversion angle at initial contact during landing and running tasks and therefore may not attenuate the risk of ankle sprains for individuals with CAI by this mechanism. However, these findings included a small number of studies that were of mostly low to moderate quality, reducing the certainty of the evidence.

Reductions in frontal-plane excursion were found between external ankle support and no external ankle support for individuals with CAI during landing but not running tasks. Authors of previous studies of healthy individuals have shown that external ankle supports reduce frontal-plane excursion during running,[54–56] but their findings were inconclusive for landing tasks.[19] Other researchers have suggested that individuals with CAI have greater frontal-plane excursion during landing[57] but not running[8] compared with healthy individuals. Our meta-analyses showed that the addition of external ankle supports provides a small reduction

A

Study and Subgroup	External Ankle Support Group: Mean ± SD, °	External Ankle Support Group: Total, No.	Control Group: Mean ± SD, °	Control Group: Total, No.	Weight, %	Mean Difference, Inverse Variance, Random (95% CI)
Agres et al,[38] (2019), semirigid bracing	26.7 ± 7	16	28.7 ± 7.5	16	21.3	−2.00 (−7.03, 3.03)
De Ridder et al,[40] (2015), semirigid bracing	32.8 ± 5.7	28	36.1 ± 5.9	28	58.2	−3.30 (−6.34, −0.26)
Zhang et al, [50] (2012), semirigid bracing	8.1 ± 4.9	5	16.6 ± 6.3	5	11.0	−8.50 (−15.50, −1.50)
Zhang et al, [50] (2015), soft bracing	10.5 ± 5.8	5	16.6 ± 6.3	5	9.5	−6.10 (−13.61, 1.41)
Total		54		54	100.0	−3.86 (−6.18, −1.54)

Heterogeneity: $\tau^2 = 0.00$, $\chi^2_3 = 2.69$, $P = .44$, $I^2 = 0\%$
Test for overall effect: $Z = 3.26$, $P = .001$



B

Study and Subgroup	External Ankle Support Group: Mean ± SD, °	External Ankle Support Group: Total, No.	Control Group: Mean ± SD, °	Control Group: Total, No.	Weight, %	Mean Difference, Inverse Variance, Random (95% CI)
Agres et al,[38] (2019), semirigid bracing	41.5 ± 6.6	16	43.4 ± 6.6	16	11.4	−1.90 (−6.47, 2.67)
De Ridder et al,[40] (2015), semirigid bracing	40 ± 5.3	28	43.5 ± 6	28	27.2	−3.50 (−6.47, −0.53)
McKelle Ulm et al,[41] (2015), semirigid bracing	29.8 ± 3.2	4	30.8 ± 7	4	4.2	−1.00 (−8.54, 6.54)
Zhang et al, [50] (2012), semirigid bracing	30.8 ± 5.8	5	39.2 ± 8.9	5	2.8	−8.40 (−17.71, 0.91)
McKelle Ulm et al,[41] (2015), nonelastic taping	28.3 ± 3.1	3	30.8 ± 7	3	3.2	−2.50 (−11.16, 6.16)
Zhang et al, [50] (2012), soft bracing	32.8 ± 6.8	5	39.2 ± 8.9	5	2.5	−6.40 (−16.22, 3.42)
Sarvestan et al,[47] (2020), elastic taping	32.95 ± 4.42	28	36.58 ± 4.03	28	48.7	−3.63 (−5.85, −1.41)
Total		89		89	100.0	−3.45 (−5.00, −1.90)

Heterogeneity: $\tau^2 = 0.00$, $\chi^2_6 = 2.35$, $P = .88$, $I^2 = 0\%$
Test for overall effect: $Z = 4.37$, $P < .001$

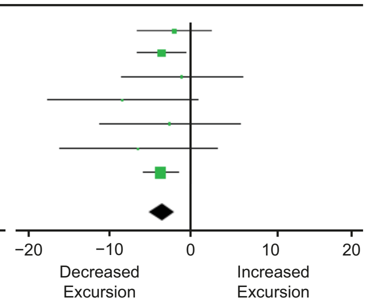


Figure 6. Meta-analysis forest plots showing the effects of external ankle support on A, plantar-flexion angle at initial contact, and B, sagittal-plane excursion during landing.

(−1.83°) in frontal-plane excursion during landing. The reduction in frontal-plane excursion for individuals with CAI using external ankle supports possibly could reduce the severity of an ankle sprain by limiting peak inversion angle during an ankle-sprain mechanism, such as an awkward landing or standing on another player's foot. Meta-analyses for running showed a similar mean difference (−1.31°) that was not different because of a wider CI and was likely to have been affected by a smaller sample size and larger statistical heterogeneity ($I^2 = 51\%$).

We found that external ankle supports reduce plantar-flexion angle at initial contact for individuals with CAI during landing but not running tasks. This finding was consistent with the findings of researchers investigating external ankle supports in healthy individuals.[19,53] Individuals with CAI have a less plantar-flexed ankle before landing[11] but a more plantar-flexed ankle during running[8] compared with healthy individuals. Our meta-analysis showed that the addition of external ankle supports leads to a large reduction (−3.86°) in plantar-flexion angle during initial contact during landing tasks. This reduced plantar-flexion angle at initial contact is likely to place the ankle in a more stable closed-packed position, which may reduce the risk of an ankle sprain.[11,58] No difference between external ankle support and no external ankle support was found in plantar-flexion angle at initial contact during running tasks. Limited studies, small numbers of participants, and methodological inconsistencies were likely responsible for the high statistical heterogeneity ($I^2 = 85\%$) and an inconclusive finding.

Reductions in sagittal-plane excursion were found between external ankle support and no external ankle support for individuals with CAI during landing and running tasks. This finding is consistent with that of researchers investigating external ankle supports in healthy individuals.[19] Individuals with CAI have less sagittal-plane motion than healthy individuals during landing[11,57] but not running.[8] The reason why individuals with CAI have reduced sagittal-plane excursion is unclear; however, some researchers have suggested that participants with CAI prefer a closed-packed position for mechanical stability or may have restricted joint movement.[4,58] The addition of external ankle supports results in a large reduction for both landing (−3.45°) and running (−5.21°). Given that mean dorsiflexion range of motion for individuals with CAI is approximately 41°,[59] the effects of further restriction on sagittal-plane excursion for individuals with CAI are unclear. Future studies should be done to investigate this consequence on proximal compensatory patterns and ankle-sprain risk. Reductions in dorsiflexion velocity but not plantar-flexion moment, peak vGRF, time to peak force, and loading rates were found between external ankle support and no external ankle support for individuals with CAI. Reduced dorsiflexion velocity may result from mechanical restrictions from external ankle supports in addition to secondary internal changes such as tight calf musculature or restricted talocrural arthrokinematics and osteokinematics in this population.[60]

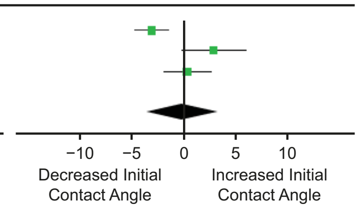
STRENGTHS AND LIMITATIONS

We investigated the biomechanical effects of external ankle supports on individuals with CAI when performing sport-related tasks. Where possible, we performed robust

A

Study and Subgroup	External Ankle Support Group: Mean ± SD, °	Total, No.	Control Group: Mean ± SD, °	Total, No.	Weight, %	Mean Difference, Inverse Variance, Random (95% CI)
Chinn et al,[39] (2014), nonelastic taping	4.89 ± 1.55	7	7.96 ± 1.58	7	36.2	−3.07 (−4.71, −1.43)
Deschamps et al,[43] (2016), nonelastic taping	11.9 ± 5	15	9 ± 3.4	15	30.0	2.90 (−0.16, 5.96)
Stotz et al,[49] (2021), soft bracing	2.69 ± 2.65	14	2.34 ± 3.4	14	33.7	0.35 (−1.91, 2.61)
Total		36		36	100.0	−0.12 (−3.54, 3.29)

Heterogeneity: $\tau^2 = 7.69$, $\chi^2_2 = 13.69$, $P = .001$, $I^2 = 85\%$
Test for overall effect: $Z = 0.07$, $P = .94$



B

Study and Subgroup	External Ankle Support Group: Mean ± SD, °	Total, No.	Control Group: Mean ± SD, °	Total, No.	Weight, %	Mean Difference, Inverse Variance, Random (95% CI)
Chinn et al,[39] (2014), nonelastic taping	40.05 ± 12.02	7	47.7 ± 14.4	7	5.6	−7.65 (−21.55, 6.25)
Deltour et al,[42] (2021), nonelastic taping	45.3 ± 12.9	15	52.2 ± 15.6	15	9.8	−6.90 (−17.14, 3.34)
Deschamps et al,[43] (2016), nonelastic taping	34.3 ± 5.9	15	43.1 ± 6.3	15	36.7	−8.80 (−13.17, −4.43)
Sarvestan et al,[48] (2019), nonelastic taping	70.04 ± 20.17	13	69.35 ± 18.62	13	4.9	0.60 (−14.23, 15.61)
Stotz et al,[49] (2021), soft bracing	51.58 ± 5.69	14	54.45 ± 5.63	14	38.5	−2.87 (−7.06, 1.32)
Sarvestan et al,[48] (2019), elastic taping	73.56 ± 19.89	12	69.35 ± 18.62	12	4.6	4.21 (−11.21, 19.63)
Total		76		76	100.0	−5.21 (−8.59, −1.83)

Heterogeneity: $\tau^2 = 3.13$, $\chi^2_5 = 6.04$, $P = .30$, $I^2 = 17\%$
Test for overall effect: $Z = 3.02$, $P = .003$

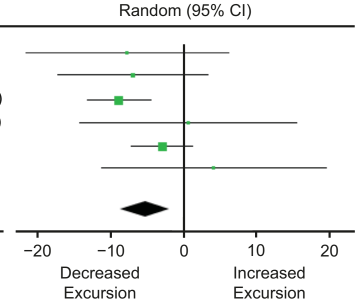


Figure 7. Meta-analysis forest plots showing the effects of external ankle support on A, plantar-flexion angle at initial contact, and B, sagittal-plane excursion during running.

meta-analyses to better understand how external ankle supports influence ankle biomechanics associated with ankle-sprain risk in individuals with CAI. Our inclusion of studies that assessed ankle biomechanics during landing, running, and change-of-direction tasks is also a strength, given that these are the sporting tasks during which sprains most commonly occur. However, some limitations should be acknowledged. The included studies were primarily of low to moderate quality, with heterogeneity and variability in inclusion criteria, types of external ankle support used, taping strategies, and task protocols. A lack of consistency existed in the inclusion criteria of participants among studies, and few studies followed the selection criteria for participants with CAI endorsed by the International Ankle Consortium.[6] Inconsistencies in participant characteristics potentially contributed to greater heterogeneity and less certainty of the effect estimates. Furthermore, various external ankle support types were used and were pooled into meta-analyses for all outcomes. It is possible that some external ankle supports with greater rigidity (semirigid bracing or nonelastic taping) may have a greater effect on ankle biomechanics. Therefore, pooled estimates may be influenced by the types of external ankle supports used in each study contributing to the meta-analysis.

CLINICAL IMPLICATIONS AND FUTURE STUDIES

The current evidence indicates that clinicians may consider external ankle supports for athletes with CAI to reduce the risk of subsequent ankle sprains, particularly during landing tasks. When interpreting these findings, restricting frontal-plane excursion could limit peak inversion angle during an awkward landing or player-contact mechanism and may protect against or reduce the severity of an ankle sprain. However, clinicians should use considerable caution when interpreting these findings. The level of certainty was very low to low across all outcomes because of small sample sizes with variability in participant characteristics, study methodologies, and various types of external ankle supports. In addition, future research should be done to consider further high-quality studies with larger sample sizes and consistent methodological protocols, and we strongly recommend using selection criteria for CAI for research participants.[6] More research is needed on the various types of external ankle supports used during sport-related tasks (ie, landing, running, and change of direction) to better understand their effects on ankle biomechanics in individuals with CAI. This will provide more conclusive findings and enable a greater possibility of translating laboratory-based biomechanical research into clinical and sporting practice.

CONCLUSIONS

In this systematic review, we found very low-certainty evidence that external ankle supports reduce frontal-plane excursion during landing but not inversion angle at initial contact, in individuals with CAI. Frontal-plane kinematics were not influenced by external ankle supports during running tasks. We also observed low- to very low-certainty evidence for sagittal-plane restrictions with external ankle supports for landing and running tasks, notably reduced excursion. Given insufficient studies, determining the effect of external ankle supports during change-of-direction tasks is difficult. These findings may provide insight into potential ankle-sprain risk-mitigation strategies with external ankle supports for individuals with CAI.

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SUPPLEMENTAL MATERIAL

Supplemental Table 1.

Found at DOI: https://doi.org/10.4085/208.22.S1

Supplemental Table 2.

Found at DOI: https://doi.org/10.4085/208.22.S2

Supplemental Figure 1. Forest plots showing the effects of external ankle support on A, eversion velocity, B, inversion velocity, C, eversion moment, and, D, inversion moment during landing.

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Supplemental Figure 2. Meta-analysis forest plots showing the effects of external ankle support on peak angle in the frontal plane during running.

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Supplemental Figure 3. Forest plots showing the effects of external ankle support on A, inversion angle at initial contact, B, peak inversion angle, C, angular moment, and, D, angular velocity in the frontal plane during change of direction.

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Supplemental Figure 4. Meta-analysis forest plots showing the effects of external ankle support on A, dorsiflexion velocity, B, plantar-flexion moment, C, peak vertical ground reaction force, D, time to peak force, and E, loading rate in the sagittal plane during landing.

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Supplemental Figure 5. Forest plots showing the effects of external ankle support on peak dorsiflexion angle during running.

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Supplemental Figure 6. Forest plots showing the effects of external ankle support on sagittal-plane excursion during change of direction.

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Address correspondence to Patrick L. Rowe, MPhysioPrac, University of Melbourne, Level 7 Alan Gilbert Building, 161 Barry Street, Parkville, Victoria 3052, Australia. Address email to patrick.rowe@student.unimelb.edu.au.