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Effects of acupuncture or similar needling therapy on pain, proprioception, balance, and self-reported function in individuals with chronic ankle instability: A systematic review and meta-analysis

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ABSTRACT

Objective: Acupuncture or similar needling therapy has long been used to improve well-being, but its effectiveness in management of chronic ankle instability (CAI) is unclear. To investigate the efficacy of acupuncture or similar needling therapy on pain, proprioception, balance, and self-reported function in individuals with CAI.

Methods: Nine databases (PubMed, Embase, Cochrane Library, Web of Science, EBSCO, PEDro, CNKI, WanFang, and CQVIP) were systematically searched from inception to April 2023. This study included randomized controlled trials involving acupuncture or similar needling therapy as an intervention for individuals with CAI. Data were extracted independently by two assessors using a standardized form. Literature quality and risk bias were assessed by using the PEDro scale.

Results: Twelve trials (n = 571) were found, of which the final meta-analysis was conducted with eight. Different studies employ varying treatments, including specific needle types, techniques, and therapeutic frameworks. Compared to control without acupuncture or similar needling therapy, acupuncture or similar needling intervention resulted in improved pain (WMD 1.33, 95 % CI 0.14–2.52, I^2=90 %, $p = 0.03$), proprioception (active joint position sense, WMD 1.71, 95 % CI 0.95–2.48, I^2=0 %, $p < 0.0001$), balance (SMD 0.54, 95 % CI 0.03–1.04, I^2=46 %, $p = 0.04$), and self-reported function (Cumberland Ankle Instability Tool (WMD 2.92, 95 % CI 0.94–4.90, I^2=78 %, $p = 0.004$); American Orthopedic Foot and Ankle Society (WMD 9.36, 95 % CI 6.57–12.15, I^2=0 %, $p < 0.001$); Foot and Ankle Ability Measure: activities of daily living (WMD 5.09, 95 % CI 1.74–8.44, I^2=0 %, $p = 0.003$)) for individuals with CAI.

Conclusions: The available evidence suggests that acupuncture or similar needling therapy may improve pain, proprioception, balance, and self-reported function in individuals with CAI, but more trials are needed to verify these findings. Furthermore, various needles and techniques using in different studies have resulted in methodologic limitations that should be addressed in the future.

Abbreviations: CAI, chronic ankle instability; RCTs, randomized controlled trials; VAS, visual analogue scales; NPRS, numerical pain rating scale; JPSA, joint position sense active; JPSP, joint position sense passive; KT, kinaesthesia; SEBT, star excursion balance tests; AP, anterior-posterior; ML, medial-lateral; CAIT, Cumberland Ankle Instability Tool; AOFAS, American Orthopedic Foot and Ankle Society; FAAM, Foot and Ankle Ability Measure; ADL, activities of daily living; CI, confidence intervals.

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1. Introduction

The most common injury in physically active individuals is ankle sprain, and recurrence rates have been found to be as high as 80 %.[1] After an initial ankle sprain, those who have recurrent ankle sprains, the feeling of having an unstable ankle, and frequent episodes of giving way may suffer from chronic ankle instability (CAI).[2,3] Individuals with CAI usually have functional impairments, such as pain, diminished proprioception, and reduced balance control, which can affect their participation in sport, daily activities, and quality of life.[2] Therefore, interventions that aim to improve functional impairments and enhance self-reported function may play a critical role in the management of CAI.

Some of the non-surgical intervention options for CAI are exercise therapy, manual therapy, and electronic physical therapy modalities,[4,5] and there is evidence that these interventions may reduce pain and disability and improve quality of life in individuals with CAI.[6] However, an increasing number of studies have suggested that a bio-psycho-social model should be adopted to manage chronic musculoskeletal conditions.[7] In this context, culturally-adapted interventions for CAI may be an addition to patient-centered, individualized health care system.

Acupuncture is a non-pharmacological treatment modality that has widely been used in Asian countries such as China, Japan and South Korea,[8] and it is becoming more popular in western countries,[9] especially in their expanding Asian communities.[8] It involves the use of various types of needles, and practitioners often select specific tools based on their therapeutic objectives and symptoms; for instance, “filiform needles” that are commonly used in clinical practice are available in several sizes, with varying lengths and thicknesses, and each designed to address distinct conditions.[10–12] Moreover, the diversity of acupuncture instruments is not the only aspect; there are also several methods of acupuncture treatment. For example, electroacupuncture is based on the Traditional Chinese medicine framework of meridians and acupoints, but it differs from the manual needling technique as it involves stimulating the needles with an electric current.[10,13] In some cases, acupuncture treatment involves the application of heated moxibustion sticks to the needles.[10,13]

On the other hand, “Yuanli needles”, derived from traditional acupuncture, represent a novel approach that incorporates modern anatomical knowledge and principles of sports medicine, making the process more straightforward and efficient.[8,14] Similarly, in Western, “dry needling” shares similarities with Yuanli needles. Focusing on muscle tissue characteristics rather than acupoints and energy flow, dry needling involves fewer needle insertions and simpler techniques.[9] While these methods may differ in frameworks and cannot be considered identical, they all utilize needle therapy and follow operational procedures akin to traditional acupuncture. Hence, in this review, all of them were referred to as an acupuncture or similar needling therapy.

As a therapeutic modality for CAI, acupuncture or similar needling therapy is the insertion of needles in some special points for certain minutes which aims to improve muscle filament overlap and sensorimotor function, and it has already shown to have some benefits.[8,15] For example, recent studies with CAI have reported an improvement in self-reported function after acupuncture or similar needling therapy that was small to moderate.[15,16] Additionally, it has been observed that acupuncture or similar needling therapy may be also effective for enhancing proprioception of the ankle joint in individuals with CAI.[16]

Although there has recently been an increased number of studies evaluating the effectiveness of acupuncture or similar needling therapy in individuals with CAI, they have not yet been synthesized into a systematic review, and the differences in their results suggest that the efficacy of acupuncture or similar needling therapy for CAI is still unclear. Therefore, the aim of the present study was to comprehensively assess, through conducting a meta-analysis, the effects of acupuncture or similar needling therapy on functional impairments such as pain, proprioceptive deficits, poor balance control, and self-reported function, as measured by self-administered questionnaire, in individuals with CAI.

2. Methods

This study was reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020 statement) guidelines,[17] and it was registered in the International Prospective Register of Systematic Reviews (PROSPERO) database (registration number: CRD42022307027).

2.1. Data sources and searches

A search for eligible articles indexed in PubMed, Embase, Cochrane Library, Web of Science, EBSCO, PEDro, CNKI, WanFang, and CQVIP was updated on April 2023. The database search strings contained synonyms for acupuncture or similar needling therapy and CAI, and keywords were added when optional. The search string is available in the Supplementary 1. There was no restriction of language and publication year.

2.2. Study Selection

Two assessors (L.L. and J.H.) each independently selected the studies. Both of them scrutinized the titles/abstracts of all the searched articles, and any trial with accessible full-text was retrieved if it was judged to be potentially eligible by at least one assessor. After the full texts of all potentially eligible retrieved trials had been evaluated, both assessors made an independent decision to include or exclude each trial. When selection disagreements could not be resolved by discussion, a third reviewer made the final consensus-based decision.

Any identified study was included if it was a trial involving participants with ankle instability, in which acupuncture or similar needling therapy was applied to participants’ limbs or trunk, and in which pain, proprioception, balance, and/or self-reported function were/was reported.

Studies were included by following the PICOS criteria: (1) participants: individuals with ankle instability; (2) intervention: acupuncture or similar needling therapy; (3) comparators: no restriction; (4) outcomes: there was no restriction in terms of outcome measures, but this meta-analysis focused on the pain, proprioception, balance, and self-reported function; (5) study design: randomized controlled trials (RCTs).

The exclusion criteria were as follows: (1) trials conducted in animals, in vitro, cadavers, simulators or prosthesis; (2) participants had acute ankle sprain; (3) articles were case reports, or descriptive studies, or not published as peer-reviewed journal articles, including book chapters and conference abstracts.

2.3. Quality evaluation and risk of bias assessment

Two assessors each independently evaluated all included trials for literature quality and risk of bias, using the PEDro scale,[18] which is reliable for assessing each study.[19,20] The PEDro scale consists of 11 items with a total score ranging from 0 to 10 (the first item is not scored), and each item is scored “YES” (1 point) or “NO” (0 point); a study with a score above 6 is considered as high quality, and a score of less than 6 for a study would reflect greater potential for biases to affect the results of the trial.[18] When disagreements could not be resolved by discussion, a third reviewer made the final decision.

2.4. Data extraction and outcome measures

Two reviewers each independently extracted the data for meta-analysis. Basic information including the main criteria for ankle instability, participant characteristics (age, sex, height, weight), experimental and control intervention measures, and documented analyzable outcomes. In particular, the acupuncture or similar needling therapy characteristics of included studies were collected for comparison. Disagreements were resolved by a third reviewer.

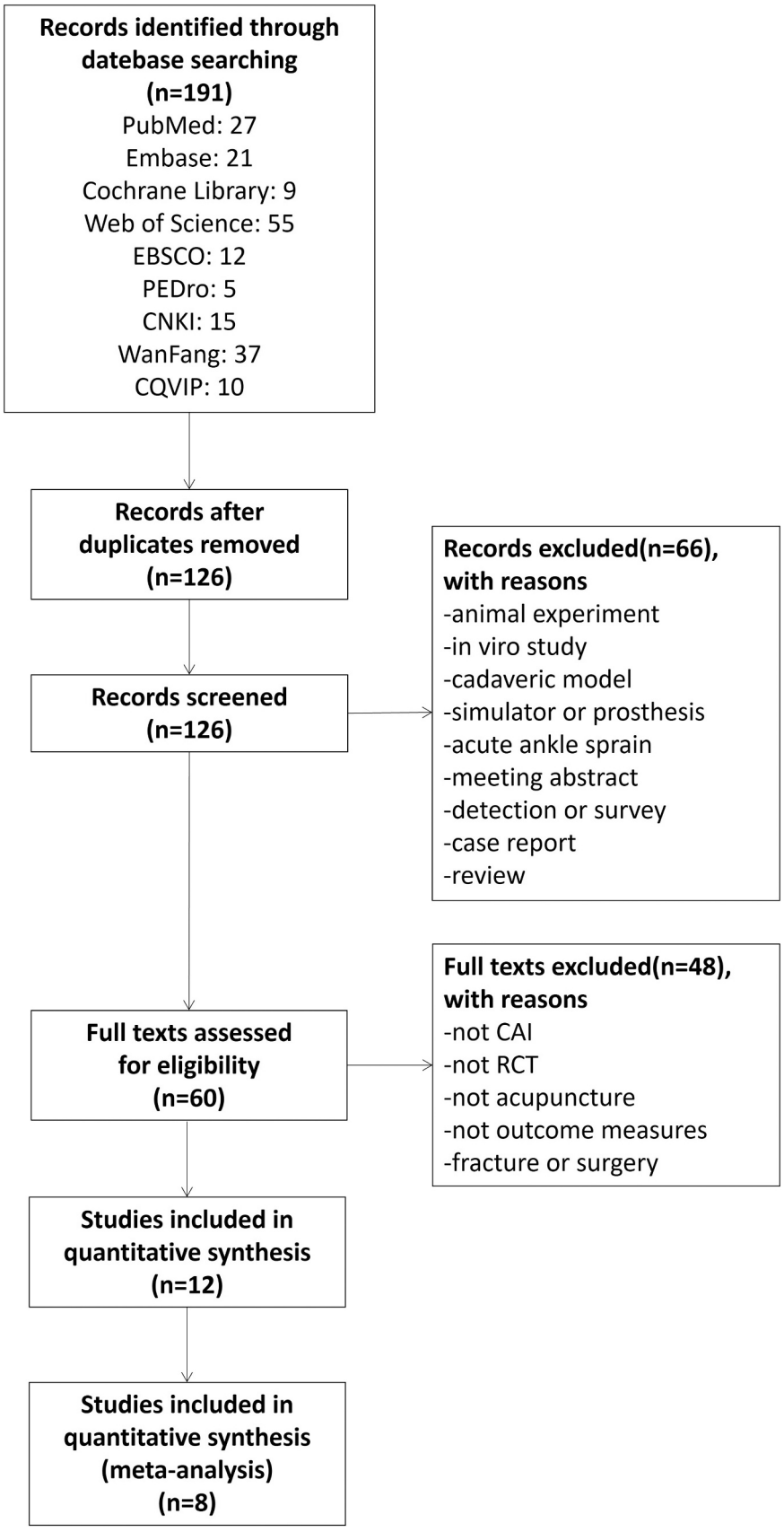

Fig. 1. Flowchart of study selection.

Table 1
PEDro scores of included studies.

Study	Eligibility criteria	Random allocation	Concealed allocation	Groups similar at baseline	Participant blinding	Therapist blinding	Assessor blinding	< 15 % dropouts	Intention to treat analysis	Between group difference reported	Point estimate & variability reported	Total (0–10)
Ning et al., 2020	YES	NO	NO	YES	NO	NO	NO	YES	YES	YES	YES	5
Rossi et al., 2017	YES	YES	YES	YES	NO	NO	YES	YES	YES	NO	YES	7
Salom-Moreno et al., 2015	YES	YES	YES	YES	NO	NO	NO	YES	YES	YES	YES	7
Song et al., 2021	YES	NO	NO	YES	NO	NO	NO	YES	YES	YES	YES	5
Wu, 2019	YES	YES	NO	YES	NO	NO	NO	YES	YES	YES	YES	6
Yang, 2014	YES	YES	NO	NO	NO	NO	NO	YES	YES	NO	YES	4
Zhou et al., 2019	YES	YES	NO	YES	NO	NO	NO	YES	YES	YES	YES	6
Zhu et al., 2013	YES	YES	NO	YES	NO	NO	NO	YES	YES	NO	YES	5
*Geist et al., 2021	YES	YES	YES	YES	NO	YES	YES	NO	NO	YES	YES	7
*Lopez-Gonzalez et al., 2021	YES	YES	NO	YES	NO	NO	YES	YES	YES	YES	YES	7
*Mullins et al., 2020	YES	NO	NO	YES	NO	NO	NO	YES	YES	YES	YES	5
*Wu and Yang, 2021	YES	YES	NO	NO	NO	NO	NO	YES	YES	YES	YES	5

* The study met the inclusion criteria but was not included in the final meta-analysis since its both of intervention and control consisted of acupuncture.

In terms of pain, visual analogue scales (VAS) consist of a 10-cm horizontal line with anchor points of 0 (no pain) and 10 (worst pain imaginable);[21] similarly, the scoring of the numerical pain rating scale (NPRS) is also in the range of 0–10,[22] but it is expressed by numbers without decimal places. Although there is this limitation in decimal accuracy, it is relatively negligible, so for ease of comparison, both were considered as identical for analysis in this review. Pain measured by the Baird-Jackson instrument contains five questions, scoring from 0 to 15,[23] with a higher score representing a better condition; to unify the scoring of pain, this value was transformed to 0–10.

With regard to proprioception, the results of studies which measured using joint position sense active (JPSA), joint position sense passive (JPSP), and kinaesthesia (KT) were normalized and considered as continuous data, since they are frequently adopted to assess improvement in proprioception with high reliability and representativeness,[24,25] and they could be measures appropriate for meta-analysis, with scores at baseline and after intervention.

For balance, since measurement varies from study to study, such as those using star excursion balance tests (SEBT), and those using postural control, results had to be adjusted to the same unit for comparison, which may be divided into anterior-posterior (AP) and medial-lateral (ML) directions to analyze.

With respect to self-reported function, the outcomes were relatively easily counted, since the relevant scales such as Cumberland Ankle Instability Tool (CAIT) (which consists of 9 questions scored on a 30-point scale),[26] American Orthopedic Foot and Ankle Society (AOFAS) (which contains 9 items scored on a 100-point scale),[27] and Foot and Ankle Ability Measure (FAAM) (which consists of a 21-item sub-scale for activities of daily living (ADL), and an 8-item sub-scale for sport performance) were reported with continuous, numeric and standardized scores.[28]

2.5. *Data synthesis and statistical analysis*

A randomized effects model with the inverse variance method was used. The outcome measures of pain, proprioception, and self-reported function were calculated as the mean change score (continuous data) between pre- and post- intervention, with the weighted mean differences (WMD) and standard deviations (SD) (95 % confidence intervals (CI)). The measurements of balance vary between studies, so the standardized mean difference (SMD) was adopted to unify different outcome units. Inconsistency was evaluated by the I-squared (I^2) index (values exceeding 50 % implied a moderate to high statistical heterogeneity), and a p value less than 0.05 indicated a statistically significant difference. All meta-analyses were conducted with RevMan (Version 5.3).

3. Results

3.1. *Literature search and screening*

In total, 191 records were identified in the search, of which 12 articles[16,22,23,27,29–36] were judged eligible and included in the review (n = 571), and 8 studies[22,23,27,31–33,35,36] were included in the final meta-analysis (there were four trials[16,29,30,34] that were not included since their both of intervention and control consisted of acupuncture or similar needling therapy). The detailed selection process is presented in Fig. 1.

3.2. *Quality assessment of the included studies*

The results of the quality assessment are presented in Table 1. The mean score across all included studies was 5.75 on the PEDro scale, which ranges from 4 to 7. The main shortcoming of the included studies was that the form of randomization, allocation methods, and/or blinding performance in some trials were/was unclear, or there was a lack of the presentation of procedural detail.

Table 2
Characteristics of included studies.

Study	Main criteria of ankle instability	Experimental group		Control group		Analyzable outcomes			
		Participants	Interventions	Participants	Interventions	Pain	Proprioception	Balance	Self-reported function
Ning et al., 2020	There was no less than once single ankle sprain in 1 year, and the sprain occurred 1 month before the visit; participants felt the ankle acerbity, weakness, and decreased control function on the affected side.	N = 36 Age(year): 23.53 ± 4.14 Gender(M/F): 20/16 Height(cm): 168.44 ± 7.35 Weight(kg): 61.27 ± 16.93	Acupuncture plus Exercise (Baduanjin)	N = 36 Age(year): 22.17 ± 4.83 Gender(M/F): 21/15 Height(cm): 170.89 ± 7.82 Weight(kg): 62.20 ± 14.49	Core stability training	-	-	SEBT	CAIT
Rossi et al., 2017	Participants sustained at least one self-reported lateral ankle sprain within 12 months prior to enrolling in the trial; they had inflammatory symptoms present at the time of initial injury (pain, swelling, warmth or redness); the previous ankle sprain(s) interrupted normal physical activity for at least one day.	N = 11 Age(year): 28.8 ± 9.9 Gender(M/F): 3/8 Height(cm): 168.2 ± 11.7 Weight(kg): 68.0 ± 14.4	Acupuncture	N = 11 (Uninvolved) Age(year): 28.8 ± 9.9 Gender(M/F): 3/8 Height(cm): 168.2 ± 11.7 Weight(kg): 68.0 ± 14.4	No treatment	-	-	Balance Tests Hop Test	-
Salom-Moreno et al., 2015	A history of at least one ankle sprain; at least one episode of giving away in the previous 6 months; ankle pain of intensity > 3 points on the NPRS; score of 25 or less on the CAIT.	N = 14 Age(year): 33.0 ± 2.4 Gender(M/F): 8/6	Acupuncture plus Exercise (proprioception)	N = 13 Age(year): 33.4 ± 2.8 Gender(M/F): 7/6	Exercise (proprioception)	NPRS	-	-	FAAM_ADL FAAM_SPORTS
Song (a) et al., 2021	Participants had ankle weakness, instability and repeated sprain, and had a history of ankle sprain ≧ 1 time in the past 1 year; the first ankle sprain occurred at least 1 year before the trial, and the latest ankle sprain occurred at least 1 month before the trial; CAIT ≦ 27.5, IdFAI ≧ 11; anterior drawer test and talus tilt test were negative.	N = 18 Age(year): 41.21 ± 9.62 Gender(M/F): 7/11	Acupuncture plus Exercise	N = 18 Age(year): 42.55 ± 10.81 Gender(M/F): 9/9	No treatment	-	-	-	CAIT AOFAS FAAM_ADL FAAM_SPORTS
Song (b) et al., 2021		N = 18 Age(year): 39.79 ± 12.99 Gender(M/F): 6/12	Acupuncture						
Wu, 2019	Participants had a history of ankle sprains, the latest ankle sprain occurred at least 1 month before the trial; they felt pain and swelling of the lateral ankle, difficulty in walking, or repeated sprains, and there was local tenderness and swelling of the lateral ankle, decreased active ROM of the ankle joint, and weakened flexion and extension strength. These symptoms were more than 3 months old.	N = 46 Age(year): 38.73 ± 10.58 Gender(M/F): 19/27 Height(cm): 165.09	Acupuncture plus Ultrashort wave & Exercise	N = 46 Age(year): 40.26 ± 11.35 Gender(M/F): 21/25 Height(cm): 164.69 ± 5.03 Weight(kg): 56.15 ± 5.79	Ultrashort wave & Exercise	VAS	JPSA JPSP KT	-	AOFAS

(*continued on next page*)

Table 2 (*continued*)

Study	Main criteria of ankle instability	Experimental group		Control group		Analyzable outcomes			
		Participants	Interventions	Participants	Interventions	Pain	Proprioception	Balance	Self-reported function
		± 5.28 Weight(kg): 55.83 ± 6.21							
Yang, 2014	A history of repeated ankle sprains; CAIT < 27 points; there were obvious tender points around the ankle joint, and the inversion test and anterior-posterior stress test were positive.	N = 19	Acupuncture plus Exercise	N = 19	Exercise	-	-	Dynamic Posture Equilibrium Test	CAIT
Zhou et al., 2019	Participants had been repeatedly sprained twice or more on one ankle joint, and they felt the ankle joint was out of control and unstable; when they took part in the trial it had been more than 1 month since the last ankle sprain; anterior drawer test and talus tilt test were negative.	N = 26 Age(year): 31.62 ± 10.46 Gender(M/F): 14/12 Height(cm): 170.07 ± 8.22 Weight(kg): 63.38 ± 10.11	Acupuncture plus Exercise (resistance)	N = 25 Age(year): 30.96 ± 11.19 Gender(M/F): 13/12 Height(cm): 169.20 ± 8.36 Weight(kg): 65.12 ± 11.34	Ultrashort wave & Ultrasonic wave	B-J	-	-	AJFAT B-J
Zhu et al., 2013	A history of unilateral ankle sprain more than once but not simultaneously, the last incidence occurred 4 weeks ago; there were some objective sensations, for example, weakness, pain, functional debility and feeling of "giving way" in ankle.	N = 25 Age(year): 22.5 ± 8.5 Gender(M/F): 12/13 Weight(kg): 59.3 ± 16.7	Acupuncture	N = 25 Age(year): 21.5 ± 3.2 Gender(M/F): 11/14 Weight(kg): 62.0 ± 12.2	Low frequency of direct current electric stimulation	-	JPSA JPSP KT	-	-
*Geist et al., 2021	Subjective report of a lateral ankle sprain within the last twelve months	N = 17 Age(year): 28.0 ± 5.51 Gender(M/F): 9/8 Height(cm): 173.35 ± 10.19 Weight(kg): 74.66 ± 29.66	Acupuncture (spinal and peripheral)	N = 17 Age(year): 27.0 ± 5.41 Gender(M/F): 3/14 Height(cm): 165.71 ± 8.24 Weight(kg): 86.75 ± 43.48	Acupuncture (peripheral)	-	-	Balance Tests Hop Test	CAIT FADI
*Lopez-Gonzalez et al., 2021	The first sprain must have occurred at least 12 months before inclusion in the research study; there must have been at least 2 episodes of giving way in at least 6 months prior to inclusion in the study; recurrent sprain involves 2 or more sprains in the same ankle; CAIT score ≦ 27 and ≧ 5 affirmative answers to AII.	N = 16 Age(year): 23.76 ± 5.23 Gender(M/F): 10/6 Height(cm): 177 ± 6 Weight(kg): 74.12 ± 14.51	Acupuncture	N = 16 Age(year): 22.06 ± 4.75 Gender(M/F): 11/5 Height(cm): 178 ± 8 Weight(kg): 73.76 ± 5.98	Placebo dry needling	-	-	SLBT (center of pressure, sway variability) Neuromuscular Control (electromyographic assessment)	-

(*continued on next page*)

Table 2 (*continued*)

Study	Main criteria of ankle instability	Experimental group		Control group		Analyzable outcomes			
		Participants	Interventions	Participants	Interventions	Pain	Proprioception	Balance	Self-reported function
*Mullins et al., 2020	Individuals were in accordance with the International Ankle Consortium's position statement, which includes at least 1 significant ankle sprain, symptoms of giving way, and positive identification on both the AII and IdFAI.	N = 25 Age(year): 26 ± 9.42 Gender(M/F): 9/16 Height(cm): 173.12 ± 9.85 Weight(kg): 79.27 ± 18.02	Acupuncture	N = 25 (Healthy) Age(year): 25.76 ± 5.45 Gender(M/F): 10/15 Height(cm): 169.47 ± 9.43 Weight(kg): 68.47 ± 13	Acupuncture	-	-	SEBT Postural Control	-
*Wu and Yang, 2021	In line with the diagnostic criteria for chronic ankle instability formulated by the 10th Orthopaedic Academic Conference of the Chinese Medical Association and the 3rd International Chinese Orthopaedic Association Academic Conference.	N = 30	Penetrating the point plus Acupuncture & Exercise	N = 30	Acupuncture & Exercise	-	JPSA JPSP KT	-	AOFAS

CAIT: Cumberland Ankle Instability Tool; FADI: Functional Ankle Disability Index; AII: Ankle Instability Instrument; IdFAI: Identification of Functional Ankle Instability; FAAM: Foot and Ankle Ability Measure; ADL: activities of daily living; AOFAS: American Orthopedic Foot and Ankle Society; AJFAT: ankle joint functional assessment tool; SLBT: Single Leg Balance Test Assessment; SEBT: Star excursion balance tests; ROM: range of motion; JPSA: joint position sense active; JPSP: joint position sense passive; KT: Kinaesthesia; B-J: Baird-Jackson; NPRS: numerical pain rating scale; VAS: Visual Analogue Scale.

* The study met the inclusion criteria but was not included in the final meta-analysis since its both of intervention and control consisted of acupuncture.

3.3. Characteristics of the eligible studies

The twelve included studies were published from 2013 to 2021,[16,22,23,27,29–36] and all participants had a diagnosis of ankle instability. The main criteria for defining ankle instability,[26] characteristics of the participants, interventions of experimental and control group, and analyzable outcome measures were summarized in Table 2. Though variation in acupuncture or similar needling therapy was observed, it was possible to identify the main acupuncture or similar needling therapy characteristics of each intervention procedure, and the extracted acupuncture or similar needling therapy measures were presented in Table 3.

3.4. Meta-analysis: acupuncture or similar needling therapy versus control on pain

When compared to a control without acupuncture or similar needling therapy, acupuncture or similar needling therapy had a positive, statistically significant effect on reducing pain, although this result of meta-analysis was heterogeneous (Fig. 2) (WMD 1.33, 95 % CI 0.14–2.52, I^2=90 %, $p = 0.03$).

3.5. Meta-analysis: acupuncture or similar needling therapy versus control on proprioception

Significant improvement in proprioception following acupuncture or similar needling therapy was observed in the relevant tests (Fig. 3): (1) JPSA (WMD 1.71, 95 % CI 0.95–2.48, I^2=0 %, $p < 0.0001$); (2) JPSP (WMD 2.13, 95 % CI 1.45–2.82, I^2=0 %, $p < 0.00001$); (3) KT (WMD 0.79, 95 % CI 0.54–1.04, I^2=0 %, $p < 0.00001$).

3.6. Meta-analysis: acupuncture or similar needling therapy versus control on balance

Positive effects of acupuncture or similar needling therapy on balance were found, and these are displayed in Fig. 4. Although all three meta-analysis results were on the right-hand side of benefit, two did not reach statistical significance, and these meta-analyses found high heterogeneity: (1) Balance (SMD 0.54, 95 % CI 0.03–1.04, I^2=46 %, $p = 0.04$); (2) Balance-AP (SMD 0.36, 95 % CI −0.26 to 0.99, I^2=61 %, $p = 0.26$); (3) Balance-ML (SMD 0.54, 95 % CI −0.42 to 1.50, I^2=82 %, $p = 0.27$).

3.7. Meta-analysis: acupuncture or similar needling therapy versus control on self-reported function

Acupuncture or similar needling therapy demonstrated several benefits, as measured by self-administered questionnaire, with results for four scales displayed in Fig. 5. All of these were statistically significant: (1) CAIT (WMD 2.92, 95 % CI 0.94–4.90, I^2=78 %, $p = 0.004$); (2) AOFAS (WMD 9.36, 95 % CI 6.57–12.15, I^2=0 %, $p < 0.001$); (3) FAAM-ADL (WMD 5.09, 95 % CI 1.74–8.44, I^2=0 %, $p = 0.003$). (4) FAAM-SPORT (WMD 12.95, 95 % CI 8.39–17.52, I^2=0 %, $p < 0.001$).

4. Discussion

The current meta-analysis showed that pain, proprioception, balance, and self-reported function were improved by acupuncture or similar needling therapy when compared with control in individuals with CAI. From the mechanisms of action of acupuncture or similar needling therapy on these variables, previous studies have drawn insights from the perspectives of central and peripheral nervous system (neuromuscular control).[37,38]

For example, studies have shown that the ability of acupuncture or similar needling therapy to alleviate pain is attributed to its impact on the central nervous system.[39] Acupuncture or similar needling therapy stimulates the release of endorphins, which act as natural painkillers;

Table 3
Acupuncture or similar needling therapy characteristics of included studies.

Study	Acupuncture	Treated area	Procedure	Frequency	Follow-up
Ning et al., 2020	Traditional Chinese Acupuncture	Ashi, Kunlun, Taixi, Zusanli, Shenmai, Yanglingquan, Sanyinjiao, Zhaohai	A 0.35 × 40 mm acupuncture needle was used, the points were punctured directly with 0.5–1.0 in.. The needle was retained for 30 min, during which acupuncture therapy was performed 2–3 times.	5 sessions per week	6 weeks
Rossi et al., 2017	Trigger Point Dry Needling	fibularis longus and brevis muscles	The physical therapist identified trigger points in the fibularis longus and brevis muscles, and disposable single use Seirin brand stainless steel needles (0.30 ×40 mm) were used. The patient was moved to the sidelying position, and the physical therapist then administered trigger point dry needling to the proximal trigger point using a pistoning and fanning method (changing the inclination angle of the needle) for at least 30 s at approximately 1 Hz. If after 30 s the trigger point had not yet cleared, the pistoning and fanning technique was continued until the physical therapist no longer observed any visible or palpable muscle twitches. The same technique was then applied to the distal fibularis brevis muscle, (during the five minute "in situ" time on the fibularis longus). The needle was left in the fibularis longus and the fibularis brevis for an additional five minutes at each site.	1 session	1 week
Salom-Moreno et al., 2015	Trigger Point Dry Needling	lateral peroneus muscle	Patients received treatment with disposable stainless steel needles (0.3 ×30 mm,Novasan) that were inserted into the skin over the trigger point area. The fast-in and fast-out technique was applied. The needle was inserted, penetrating the skin10–15 mm into the trigger points until the first local twitch response was obtained. Once the first local twitch response was obtained, the needling was moved up and down (2–3 mm vertical motions with no rotations) at approximately 1 Hz for 30–45 s	1 session	End of treatment
Song et al., 2021	Traditional Chinese Acupuncture	Taixi, Shenmai, Zhaohai, Yanglingquan, Kunlun, Jiexi	The 0.3 × 40 mm Huatuo brand acupuncture needles was used. Therapist directly or obliquely punctured each acupoint and performed the leveling, replenishing, reducing, and retained the needles for 30 min.	3 sessions per week	8 weeks
Wu, 2019	Traditional Chinese Acupuncture	Jiexi, Kunlun, Taixi, Ashi, Yanglingquan, Shenmai, Sanyinjiao, Zhaohai	Acupuncture needles of 0.35 × 40 mm Huatuo brand were used, the points were punctured directly with 0.5–1.0 in.. Therapist performed the supplementing and reducing, and the needles were retained for 30 min.	6 sessions per week	8 weeks
Yang, 2014	Traditional Chinese Acupuncture	Ashi	The side needling method was adopted, and a small degree of twisting and lifting was performed for about 1 min. The needle was performed intermittently 3–4 times, and the needle was released after 20–30 min of needle retention.	1 session per day	4 weeks
Zhou et al., 2019	Electroacupuncture	Kunlun, Qiuxu	A 0.25×40 mm disposable acupuncture needle was used, piercing the needle straight, with a depth of about 0.5–1 in.; then connecting the needle handle to a Huatuo brand SDZ-II electroacupuncture device, adopting a 2 Hz continuous wave, therapist ensured that the patient can tolerate the stimulation, and the needle is retained for 20 min	4 sessions per week	4 weeks
Zhu et al., 2013	Electroacupuncture	Jiexi, Kunlun, Qiuxu, Ashi	The needles of 0.30 × 75 mm in size were inserted slowly and perpendicularly into Jiexi about 15 mm deep, lifting, thrusting and twisting with even technique; Kulun was punctured quickly about 20 mm deep; the needles were inserted into Qiuxu and Ashi points and manipulated with even technique. When the patient had sensations of soreness and distension, low frequency electric stimulation with 200 Hz equal wave and 10 mA intensity was applied for 30 min	3 sessions per week	8 weeks
*Geist et al., 2021	Trigger Point Dry Needling	fibularis longus and brevis muscles ipsilateral and contralateral multifidi of lumbar vertebra 5	The use of a single use needle type of 30–40 mm into the fibularis longus/brevis muscles utilizing the fibula as a bony backdrop while the patient was positioned in sidelying. Participants were positioned in prone with the relevant spinal level treated using a Seirin L-type 50 mm needle. The needle was inserted into the appropriate spinal segment to the level of the spinal lamina/multifidi muscle to a depth no greater than three-quarters length of the needle for 30 s using a vertical pistoning technique and then statically for 5 min	2 sessions (Initial visit, After 1 week)	1 week
*Lopez-Gonzalez et al., 2021	Trigger Point Dry Needling	peroneus longus and tibialis anterior	The physiotherapist located the most painful latent myofascial trigger points of each muscle and used a needle, sized 0.25 × 0.25 × 50 mm, for needling (Hong technique) at a frequency of 1 Hz for 30 s (1 puncture per second). After the first twitch response was obtained, the needle moved vertically 2–3 mm at this frequency. For the placebo group, the same procedure was carried out using placebo needles with the same needle size that did not puncture the skin surface but provoked a needle stick feeling. The handle of these placebo needles was pushed over the needle as soon as it touched the skin, appearing as though the skin was being penetrated, even though it was not.	1 session	48 h
*Mullins et al., 2020	Trigger Point Dry Needling	fibularis longus	Before needling, the fibularis longus was assessed for the presence of trigger points within a taut band of muscle using established	1 session	End of treatment

(*continued on next page*)

Table 3 (*continued*)

Study	Acupuncture	Treated area	Procedure	Frequency	Follow-up
			criteria that identify trigger points as tender areas or palpable nodules within the skeletal muscle. After the trigger point was identified, a sterile and disposable acupuncture needle, size 0.30 × 0.30 mm was inserted into the trigger point. Once the needle was inserted, the trigger point was treated using a "positioning" or "fast in, fast out" technique. A total of 3 needles were used, for 1 insertion each.		
*Wu and Yang, 2021	Traditional Chinese Acupuncture	Qiuxu, Zhaohai	A 2.50 cm 30-gauge disposable filigree needle was rapidly inserted into the acupoints in sequence, and the needle was retained for 30 min. Penetrating: A 75 mm long filigree needle was used to penetrate from Qiuxu point to Zhaohai point, slowly penetrate through the gap between the bones of the ankle joint, and see the needle tip peristalsis at Zhaohai point. Needles were inserted about 5.0–6.25 cm, and the left counterclockwise and the right clockwise twirling and draining method were performed for 30 min. After the operation, the filiform needle was slowly raised to 2.5–3.75 cm, and the needle was retained for 30 min.	6 sessions per week	4 weeks

* The study met the inclusion criteria but was not included in the final meta-analysis since its both of intervention and control consisted of acupuncture.

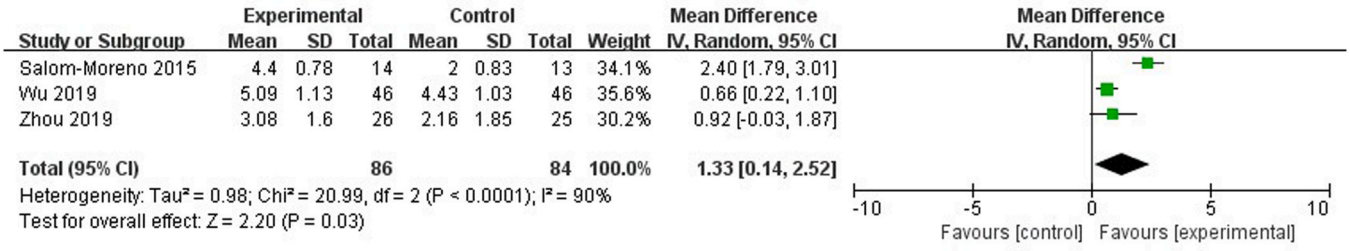

Fig. 2. Forest plot of the pain in acupuncture versus control.

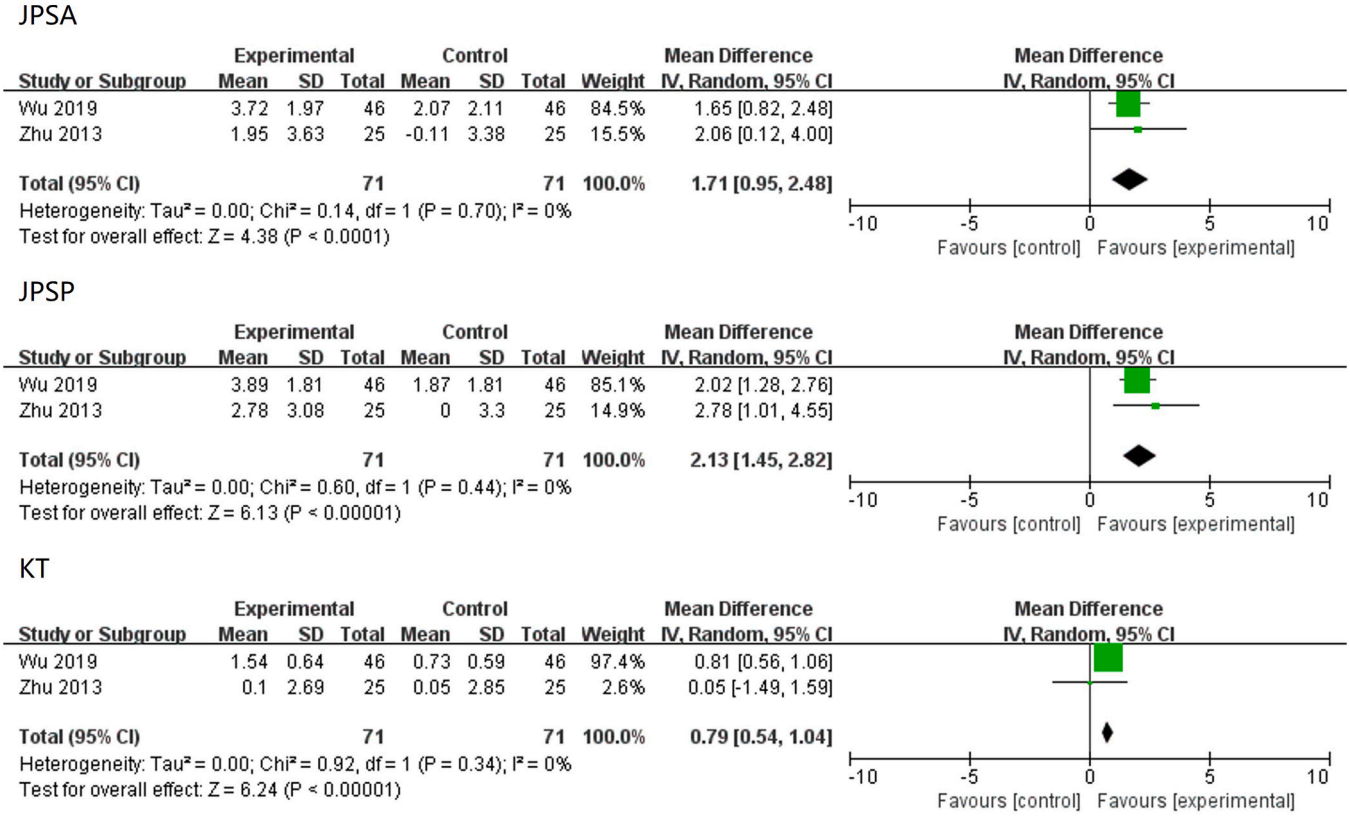

Fig. 3. Forest plot of the proprioception in acupuncture versus control.

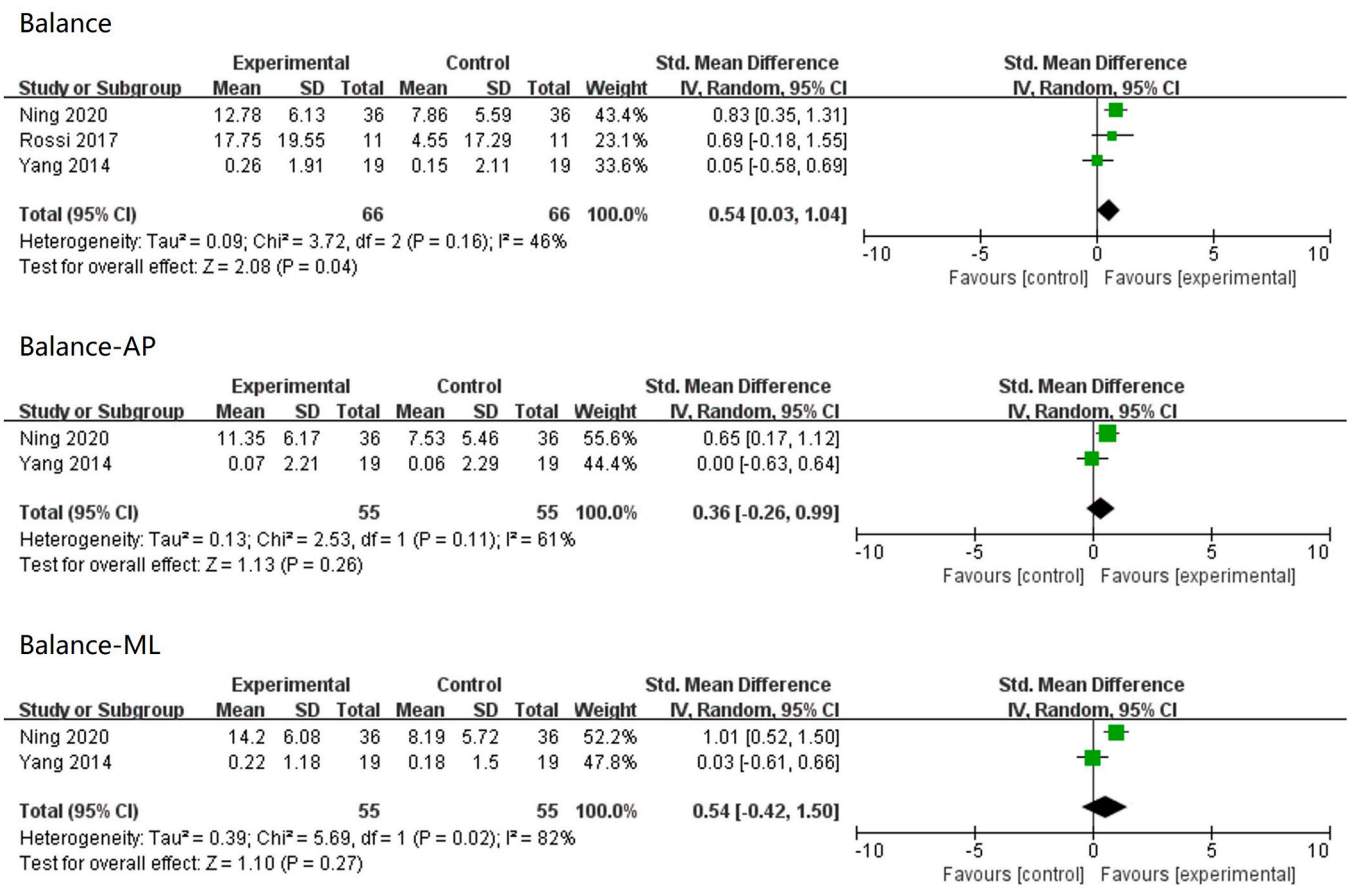

Fig. 4. Forest plot of the functional measurement in acupuncture versus control.

additionally, it activates descending pain-inhibitory pathways, reducing pain perception and increasing pain tolerance.[13,39]

Also, acupuncture or similar needling therapy has been found to influence proprioceptive feedback loops by stimulating sensory receptors in muscles and tendons; this improves proprioceptive acuity, contributing to enhanced joint stability and motor performance.[40] Not only that, studies indicate that acupuncture or similar needling therapy modulates the vestibular system and sensory inputs, leading to improved postural stability and reduced risk of falls.[41]

Based on these, the overall functional improvements reported by patients after acupuncture or similar needling therapy treatment may be attributed to a combination of pain relief, enhanced proprioception, and improved balance. In brief, the holistic approach of acupuncture or similar needling therapy to addressing underlying issues contributes to better self-reported function and overall quality of life.[42]

Specifically, in terms of pain, acupuncture or similar needling therapy showed a significant improvement effect, but the effect was relatively mild (the WMDs of two studies[23,33] were 0.66 and 0.92, respectively). There are some possible mechanisms underlying this pain-relieving effect of acupuncture or similar needling therapy in individuals with CAI. First, the analgesia effect may be due to the fact that acupuncture or similar needling therapy involves short and strong stimulation, which produces a sense of pain itself.[32,34] This may increase the pain threshold and alleviate the sense of persistent pain associated with CAI.[15,21] In addition, acupuncture or similar needling therapy has been shown to have multiple effects on the central and peripheral nervous systems,[43] and it may also promote the release of endogenous opioids, serotonin, and norepinephrine, which may have positive effects on some of the worsening factors existing after ankle sprain, such as nociception, inflammatory cytokines, and other physiologic mechanisms.[44] These can change pain perception,[44] so that individuals with CAI would feel less pain.

Although acupuncture or similar needling therapy has been shown to be helpful in some pain syndromes,[43] recommendations are generally not strong, and most of the effectiveness is low or moderate.[45,46] From the result of this meta-analysis, the improvement of pain after acupuncture or similar needling therapy was not ideal (the lower bound of the 95 % CI was 0.14), which was similar to the previous findings.[45] However, one study (Salom-Moreno 2015)[22] had a large effect on pain reduction, resulting in heterogeneity, presumably because the intervention of this study included additional active exercises. Individuals with CAI may also respond to pain with muscle tension, and tend to avoid physical activity in an attempt to avoid pain;[4] whereas it has been reported that active exercises such as stretching, joint movement and proprioceptive training can effectively alleviate pain, which may promote relaxation of the muscle fibers, metabolism within the articular capsule, and exchange of nutrients in the cartilage.[47–49] Thus, a combination of passive (acupuncture or similar needling therapy) and active (therapeutic exercise) interventions may achieve a better pain reduction effect for CAI.

With regard to proprioception, JPSA, JPSP, and KT were the methods commonly used for assessing the effectiveness of intervention in individuals with CAI.[24,25] Research has shown that individuals with CAI have deficits in ankle proprioception due to sensorimotor impairment resulting from an ankle sprain.[50,51] Therefore, when considering the management of CAI, it is important to assess proprioceptive improvement which is the ability to determine active and passive movement of a limb in space.[52,53]

From this review, all the results of meta-analysis consistently demonstrated significant improvement with good homogeneity when acupuncture or similar needling therapy was used as an intervention for CAI. This may be because acupuncture or similar needling therapy

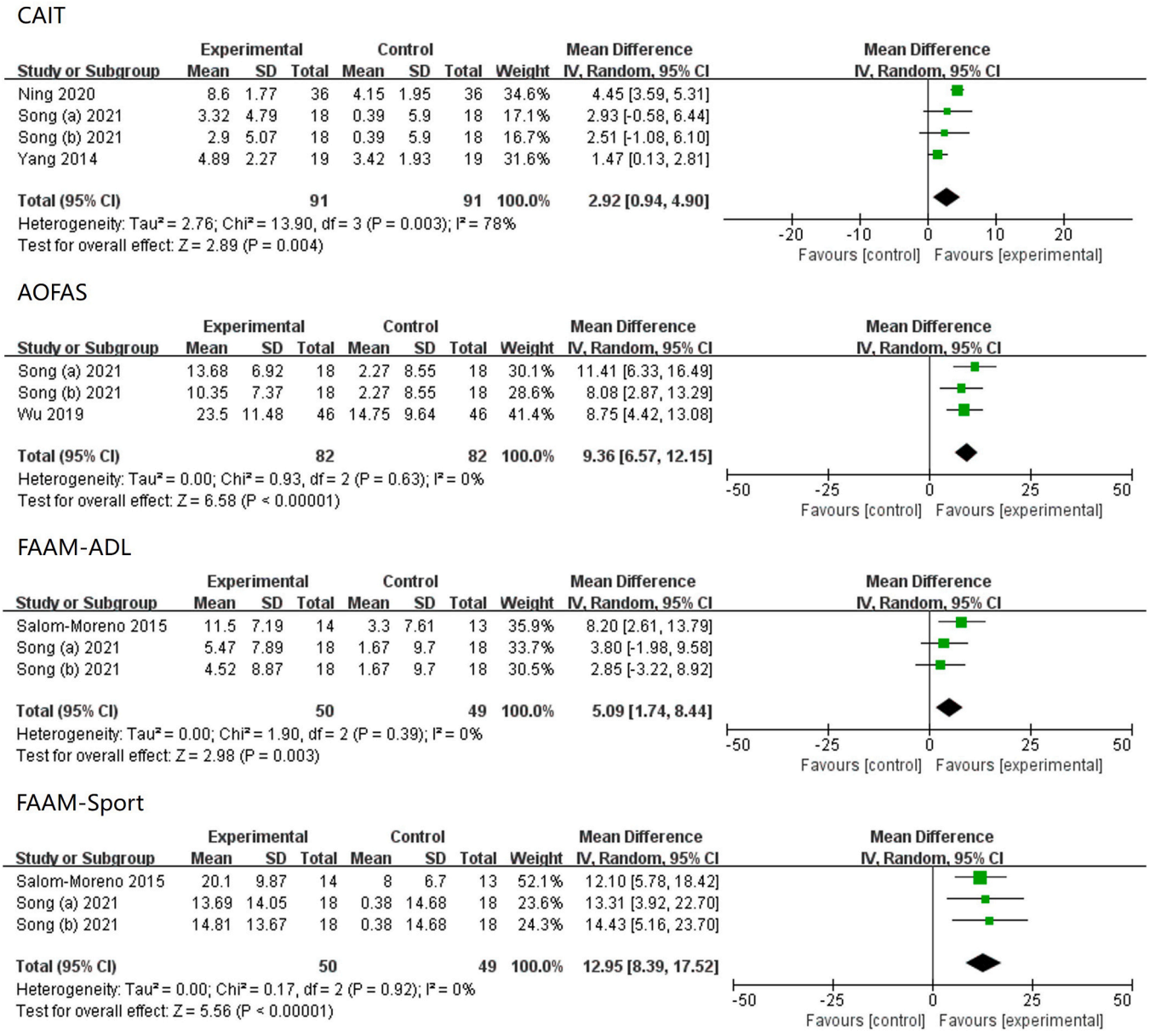

Fig. 5. Forest plot of the subjective questionnaire in acupuncture versus control.

induces limb sensitivity, especially for the treated area located in the specific trigger points or acupoints, where the needling may stimulate muscle spindles, which may be effective in enhancing the proprioceptive input from the ankle joint.[54,55]

As regards balance, the results of the meta-analysis showed that acupuncture or similar needling therapy was beneficial for overall balance in individuals with CAI. Additionally, it is worth noting that the results of meta-analysis for balance-AP and balance-ML intersected with the invalid line, which indicated that the effect of acupuncture or similar needling therapy on anterior-posterior and medial-lateral balance control in individuals with CAI seemed to be negligible.[32,35] Admittedly, both of these meta-analyses only included two studies each, and the sample sizes were relatively small; therefore, the results reported may not be highly representative.

It has been reported that most ankle sprain causes lateral ligament injuries to the ankle joint, resulting in balance deficits due to excessive ankle inversion movement in the coronal plane,[4] so that it is particularly important to manage balance in CAI. Through the stimulation from needling on trigger points or acupoints, acupuncture or similar needling therapy may strengthen blood circulation and promote metabolism around the ankle joint,[15,30,31] which effectively improves the movement disorder of foot,[29,35] and thus improves balance performance in individuals with CAI.

In addition, balance may be affected by proprioceptive input and motor output (strength).[47–49] The improvement of proprioception by acupuncture or similar needling therapy has been reported above, which may be the main reason for acupuncture or similar needling therapy improving balance.[24,25,50] However, one limitation of this review is that there were not enough studies that involved muscle strength outcome measures for the conduct of a meta-analysis, so it is uncertain whether the improvement of balance is related to any enhancement of strength associated with acupuncture or similar needling therapy.

With respect to self-reported function, four scales (CAIT, AOFAS, FAAM-ADL, and FAAM-SPORT) were included in the present meta-analysis, all of which reflected similar results that indicated that acupuncture or similar needling therapy was beneficial for improving self-reported function, with a statistical significance ($p < 0.05$). Although there was heterogeneity in the results of the meta-analysis

measured by the CAIT scale, this was mainly due to one study, (Ning 2020)[31] that combined exercise (Baduanjin, a set of medical and healing exercises originated in China) with acupuncture or similar needling therapy as the intervention, and here the improvement was particularly large. This once again pointed to the benefits of a combination of acupuncture or similar needling therapy and active exercise in the management of CAI.

The CAIT, AOFAS, and FAAM are all frequently used to evaluate ankle function and monitor the effectiveness of treatment, with high reliability and practicability.[28,35,56] Their items are representative for the assessment of subjective symptoms in individuals with CAI.[4,26,34] From the results of the current meta-analysis, they add to the current evidence that acupuncture or similar needling therapy is effective for improving self-reported function in individuals with CAI. These positive effects could be explained by applying a bio-psycho-social model. As mentioned above, acupuncture or similar needling therapy may improve a number of biological factors such as pain, proprioception, and balance. Indeed, recent studies have also found that acupuncture or similar needling therapy was effective in improving joint stiffness and range of motion when compared with no intervention.[43,57,58] In addition, acupuncture or similar needling therapy is generally well tolerated with few adverse effects, and has been considered to be a relatively safe treatment.[43,59] Based on these biological benefits, after acupuncture or similar needling therapy treatment individuals with CAI may become more compliant to engagement in physical and social activities, which may be beneficial for improving the scores on these scales, as measured by the questionnaires.

4.1. Study limitations

There were some limitations in this systematic review: (1) Only eight studies were included for meta-analysis and the sample sizes analyzed here may be too small to make conclusive evidence-based recommendations. (2) There may have been some potentially-relevant trials published in other languages that were not included. (3) There were large variations among the included studies in the acupuncture or similar needling therapy methods employed, and in the procedures of treatment, such as needling position, devices, frequency and duration. (4) There were also differences in the parameters of exercise delivered as a supplementary intervention in the respective trials, such as Baduanjin, strength training and neuromuscular control training. (5) The participants were not perfectly homogeneous with respect to their demographics. (6) Due to the challenges in implementing blinding for acupuncture or similar needling treatment and the insufficient description of random and/or concealed allocation methods in some Chinese studies, this review included several studies with relatively low PEDro scores, which could potentially introduce bias to the research findings. Therefore, extrapolation of the current results must be made with caution. Finally, some methodologic problems identified in this systematic review should be addressed in future research.

5. Conclusions

The available evidence suggests that acupuncture or similar needling therapy is beneficial for improving pain, proprioception, balance, and self-reported function in individuals with CAI. Given that the number of trials was limited and some results of the meta-analysis were heterogeneous, more high quality RCTs in individuals with CAI are needed to confirm the efficacy of acupuncture or similar needling therapy observed here on a range of outcome measures. Finally, there are variations in needles and techniques used among different studies, resulting in methodologic limitations that should be addressed in future research.

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CRediT authorship contribution statement

LL: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft. **MZ, RA, JW and AP:** Conceptualization, Methodology, Formal analysis, Writing – review & editing. **JH:** Conceptualization, Methodology, Formal analysis, Investigation, Writing – review & editing, Supervision, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ctim.2023.102983.

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