Joint Diseases and Related Surgery

Jt Dis Relat Surg
2026;37(3):637-648

ORIGINAL ARTICLE

# Comparative efficacy of conventional rehabilitation, balance acupuncture combined with conventional rehabilitation and additional unconscious proprioception training for chronic ankle instability: A randomized-controlled clinical study

Na Liu, MM[1,2,*], Mi Wang, MB[1,2,*], Qing Meng, MM[2], Mingyu Wang, MM[2], Kai Shang, MM[1], Ying-Li Bi, MM[2], Xiaowei Jiang, PhD[1,2], Jin Li, MM[2], Jiaojiao Chen, MM[2], Shiming Feng, PhD[3], Hongwei Zhai, MB[1,2]

[1]Department of Rehabilitation Medicine, Xuzhou Central Hospital, Xuzhou, Jiangsu, China
[2]Department of Rehabilitation Medicine,Xuzhou Rehabilitation Hospital, Xuzhou, Jiangu, China
[3]Department of Orthopaedics, Xuzhou Central Hospital, Xuzhou, Jiangsu, China

## ABSTRACT

**Objectives:** This study aims to compare the efficacy of conventional rehabilitation alone, conventional rehabilitation combined with balance acupuncture (BA) and conventional rehabilitation plus BA and unconscious proprioception training in chronic ankle instability (CAI) patients.

**Patients and methods:** This single-center, parallel-group, assessor-blinded randomized-controlled trial included a total of 120 CAI patients between October 2022 and October 2024. The patients were randomly assigned to control (n = 40), BA (n = 40), and combination therapy (CT, (n = 40) groups. All groups received six weeks of intervention (6 days/week): the control group received conventional rehabilitation, the BA group received conventional rehabilitation + BA and the CT group received conventional rehabilitation + BA + unconscious proprioception training. Unconscious proprioception training was defined as dual-task training using the MOTOmed system with cognitive distraction to shift focus away from conscious movement control. Assessments were conducted before and after treatment using a three-dimensional gait analysis system, a balance function testing and training system, and the Star Excursion Balance Test (SEBT).

**Results:** There was no statistically significant difference in age and sex among the groups ($p > 0.05$). In addition, disease duration and number of previous sprains were comparable among the groups ($p > 0.05$). Following the six-week intervention, all three groups showed significant improvements in gait parameters, balance function and SEBT scores compared to baseline ($p < 0.05$). The CT group exhibited significantly greater improvements in gait speed, cadence, movement length, movement ellipse area and SEBT scores than the BA group ($p < 0.05$), whereas the BA group outperformed the control group in all outcome measures ($p < 0.05$). No adverse reactions were reported in any group.

**Conclusion:** The integration of BA and unconscious proprioception training may offer additional benefits for improving gait and balance in CAI patients compared to conventional rehabilitation plus BA or conventional rehabilitation alone. Based on these preliminary findings, the combined approach shows potential clinical value for targeted populations with CAI.

***Keywords:*** Analysis, balance acupuncture, chronic ankle instability, combination therapy; gait postural balance, unconscious proprioception training.

Chronic ankle instability (CAI) is characterized by recurrent sprains, impaired postural control and proprioceptive deficits stemming from lateral ligament mechanoreceptor damage.[1,2] It severely compromises gait and daily function.[3] Proprioception training is central to CAI rehabilitation, but conventional conscious training relying on active limb control is limited

Received: December 01, 2025
Accepted: February 22, 2026
Published online: July 10, 2026

**Correspondence**: Shiming Feng, PhD. Department of Orthopaedics, Xuzhou Central Hospital, Yunlong District, Xuzhou, Jiangsu 221000, China.

E-mail: fengshiming_04@163.com

**Correspondence**: Hong-Wei Zhai, MB. Xuzhou Rehabilitation Hospital, Yunlong District, Xuzhou, Jiangsu 221000, China.

E-mail: zhw2625329@163.com

Doi: 10.52312/jdrs.2026.2311

** Na Liu and Mi Wang contributed equally to this study*

**Citation:** Liu N, Wang M, Meng Q, Wang M, Shang K, Bi YL, et al. Comparative efficacy of conventional rehabilitation, balance acupuncture combined with conventional rehabilitation and additional unconscious proprioception training for chronic ankle instability: A randomized-controlled clinical study. Jt Dis Relat Surg 2026;37(3):637-648. doi: 10.52312/jdrs.2026.2311.

by cognitive load.[4] On the contrary, unconscious proprioception training enhances automatic motor control through reflexive neuromuscular pathways (e.g., dual-task paradigms with attention distraction), directly addressing CAI's core deficit of impaired rapid perturbation responses.[5,6] Unconscious proprioceptive training is an operational definition based on established theories such as the dual-task paradigm and automatic movement control rather than a completely standardized protocol. This approach improves real-world stability and compliance,[7] with empirical support from CAI studies.[8]

Balance acupuncture (BA), a modern traditional Chinese medicine (TCM) modality, modulates central nervous system (CNS) activity via distal acupoints to reduce pain via endorphin regulation and enhance proprioception in CAI.[9] It complements proprioception training by normalizing sensory input,[10] but its combination with unconscious proprioception training remains understudied. Although conventional rehabilitation and single-modal interventions such as BA or conscious proprioception training can improve CAI outcomes, residual deficits in neuromuscular control and postural stability often persist, highlighting the need for adjunctive strategies.[11] The combination of BA (i.e., sensory modulation/pain relief) and unconscious proprioception training (i.e., automatic motor control reinforcement) may address the multifactorial pathophysiology of CAI. Balance acupuncture normalizes sensory input to facilitate motor learning,[12] whereas unconscious training strengthens the reflexive responses critical for real-world stability.[13]

To the best of our knowledge, this synergistic approach is untested in CAI, creating a key research gap. In the present study, we hypothesized that conventional rehabilitation + BA + unconscious proprioception training could yield superior gait and balance improvements to conventional therapy alone or conventional therapy + BA, providing evidence to optimize CAI rehabilitation protocols. We, therefore, aimed to compare the efficacy of conventional rehabilitation alone, conventional rehabilitation combined with BA and conventional rehabilitation plus BA and unconscious proprioception training in CAI patients.

## PATIENTS AND METHODS

### Study design and study population

This single-center, parallel-group, assessor-blinded randomized-controlled trial (RCT) was conducted at Xuzhou Rehabilitation Hospital, Department of Rehabilitation Medicine between October 2022 and October 2024. Inclusion criteria were as follows: (1) aged between 18 and 60 years; (2) a CAI diagnosis as per the International Ankle Consortium (IAC) criteria,[14] which require ≥ 2 sprains within 12 months and functional instability; (3) a Cumberland Ankle Instability Tool (CAIT) score of ≤ 24;[15] (4) no ankle sprains within the past three months; (5) no other treatments for CAI within the past six months; (6) unilateral ankle joint injury; (7) no other diseases affecting the contralateral lower limb; (8) good compliance and able to complete the training program as scheduled; and (9) no regular exercise habits (≥ 3 times/week for 30 min). Exclusion criteria were as follows: (1) the presence of other diseases causing gait abnormalities; (2) the presence of severe disease affecting vital organs; (3) a history of pathological fractures, postoperative infections or neurological injuries; (4) positive results in the anterior drawer test or talar tilt test; (5) the presence of CNS disorders, vestibular system diseases or severe visual impairments that may affect balance; (6) inability to tolerate or accept acupuncture treatment; (7) the presence of coagulation disorders or skin damage/infections at the acupuncture sites; and (8) inability to cooperate with examinations and treatment. In addition, patients who were unable to complete assessments/treatments or requested discontinuation were withdrawn from the study. Finally, a total of 120 CAI patients who met the inclusion criteria were recruited (Figure 1). A written informed consent was obtained from each patient. The study protocol was approved by the Xuzhou Rehabilitation Hospital Ethics Committee (Date: 20.10.2022, No.: XK-LW-20221020-003). The study was conducted in accordance with the principles of the Declaration of Helsinki. Clinical trial number: ChiCTR2500107213.

### Randomization

A standard random number table was used to ensure randomness and the absence of systematic patterns in the allocation. Participants were randomly assigned to three groups using a random number table method (1:1:1 ratio). The random sequence was generated by an independent statistician using the 'Random Number Generator' module in IBM SPSS version 25.0 software (IBM Corp., Armonk, NY, USA), adopting permuted block randomization with a block size of six to avoid imbalanced group allocation. Allocation concealment was implemented using sequentially numbered, opaque envelopes sealed by a non-investigator.

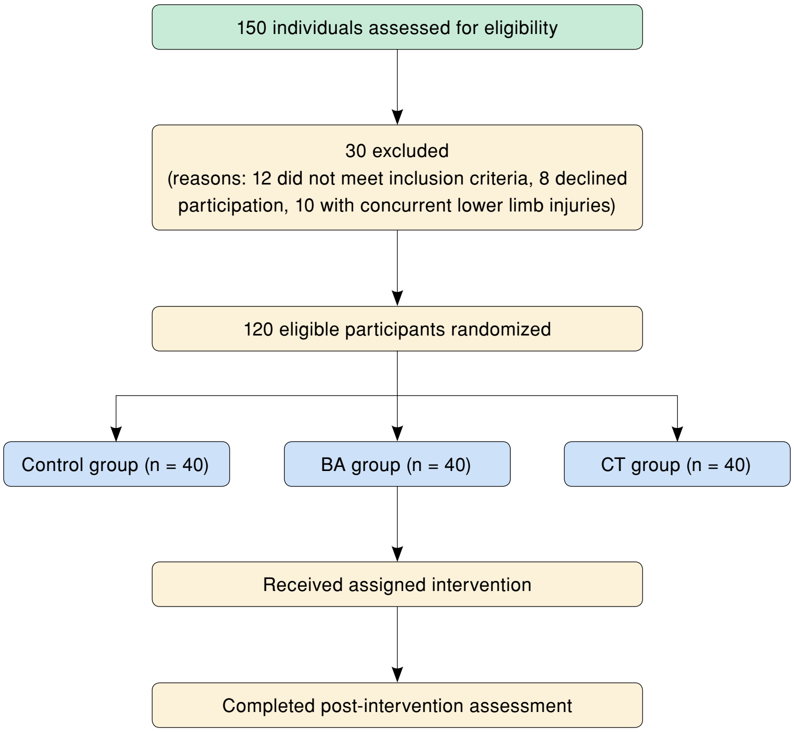


**FIGURE 1.** Study flowchart.
No participants were lost to follow-up or withdrew during the trial. All 120 randomized participants completed the intervention and post-assessment.

Envelopes were only opened by the researcher responsible for group assignment after participants completed baseline assessments, ensuring neither researchers nor participants could predict group allocation in advance. The randomization process was documented in detail, with all records retained in the study archive for audit.

In addition to blinding outcome assessors, data entry staff and statisticians were blinded to group assignments. Outcome assessors received specific training to avoid discussing intervention details with participants and were prohibited from observing any treatment sessions. To verify blinding integrity, a post-trial questionnaire was administered to assessors, asking them to rate their certainty of participant group allocation on a five-point scale (1 = completely uncertain, 5 = completely certain). The mean certainty score was 1.8 ± 0.5, confirming successful maintenance of blinding (no unblinding reported). Due to the distinct nature of BA and unconscious proprioception training, the blinding of participants and intervention providers was not feasible; to mitigate performance bias, all interventionists received standardized training on operational procedures and communication scripts and were instructed not to disclose group differences to participants.

The control group (n = 40) received conventional rehabilitation alone, the BA group (n = 40) received conventional + BA and the combination therapy (CT) group (n = 40) received conventional rehabilitation + BA + unconscious proprioception training. The trial protocol adhered to the Consolidated Standards of Reporting Trials (CONSORT) guidelines.

### Interventions

All groups received a six-week intervention (6 days/week). Each intervention session lasted 60 to 85 min in total, with specific allocations as follows:

The control group: conventional comprehensive rehabilitation therapy alone (60 min).

The BA group: conventional therapy (40 min) + BA (15 min) + a 5-min rest interval (total 60 min).

The CT group: conventional therapy (30 min) + BA (15 min) + unconscious proprioception training (30 min) + two 5-min rest intervals (total 85 min).

All sessions were designed to be feasible in clinical settings. During the study, participant compliance was ≥ 90%, and no reports of fatigue-related discomfort or injury were recorded, confirming the practicality and safety of the intervention duration.

### Conventional comprehensive rehabilitation therapy

Conventional rehabilitation components align with evidence-based guidelines for CAI.[16] Conventional comprehensive rehabilitation therapy includes the following components: (1) conventional pharmacological treatment, (2) arthrolysis, (3) joint traction therapy, (4) muscle strength and endurance training, (5) TCM herbal fumigation, and (6) proprioception training (see Supplementary).

### Balance acupuncture therapy

*Acupoint selection:* The ankle pain acupoint is located 1-cun (approximately 3.3 cm) radially from the center of the wrist crease. The selected acupoint is located on the upper limb, contralateral to the affected site. Cross-lateral needling was selected to stimulate the acupoints on the contralateral limb relative to the affected ankle.[17]

*Procedure:* The patient was placed in a supine position, and standard disinfection, in which a 75% ethanol swab was applied to the acupoint area for 30 sec, was administered. A 1-inch (approximately 2.5 cm) filiform needle (Huaguan, China) was inserted horizontally toward the center of the wrist crease at a depth of 0.3 to 0.5 cm (approximately 1 cm). The 'one-step insertion' technique was used. The patient was expected to experience a local sensation of soreness, numbness or distension, sometimes radiating to the middle finger, and the needle sensation was enhanced by the use of lifting, thrusting and rotating techniques. The therapy was administered once daily, 20 min per session, for six consecutive days, followed by one day of rest, and the treatment lasted six weeks.

### Unconscious proprioception training based on central remodeling mechanisms

*Muscle strength training:* The patient was seated and placed in the lower limb movement mode with appropriate resistance settings using the MOTOmed Intelligent Motor Training System (RECK MOTOmed GmbH, Betzenweiler, Germany). To divert patients' attention from the limb movement, they were instructed to close their eyes and listen to their favorite music or engage in other distractions. This approach activated unconscious proprioception and facilitated rhythmic lower limb movement patterns without conscious brain control. A therapist was assigned to accompany the patient throughout the training, provide real-time movement corrections and ensure safety. Based on the patient's muscle strength and tolerance, resistance was set at Levels 1-3 (Level 1: 10-15 N·m; Level 2: 15-20 N·m; Level 3: 20-30 N·m). The training parameters were set as follows:

1. Resistance level: initially set at Level 1 and progressively increased to Level 2 or 3 based on individual progress.
2. Movement speed: the initial speed was 30 to 40 repetitions per min, gradually increased to 40 to 60 repetitions per min as the patient became able to move smoothly and rhythmically.
3. Training duration: 10 min per session, 5 min forwards and 5 min backwards, with six sessions per week for six weeks.

*Balance disturbance training:* The patient stood on a training platform and chose either the balance training mode or the proprioception training mode. The difficulty level ranges from Level 3 to Level 5 and was adjusted according to individual conditions. The platform randomly shifts in a forward-backward or left-right motion, requiring the patient to maintain balance. The training parameters were set as follows:

1) In training mode, the patient can select a suitable difficulty level (Levels 3-5) by referring to the following parameters:

Level 3 - platform movement ±5°, movement frequency once every 10 sec.

Level 4 - platform movement ±10°, movement frequency once every 8 sec.

Level 5 - platform movement ±15°, movement frequency once every 6 sec.

2) Attention distractions: To enhance unconscious proprioception, a large screen was set in front of the patient playing a video the patient enjoyed, diverting attention from active balance control.

3) Training duration and frequency: The training lasted 10 to 15 min per session, with six sessions per week for six weeks.

Gait disturbance training: With the patient standing on the training platform, the therapist set the initial gait speed according to the patient's condition. During training, a touchscreen in front of the patient displayed a simple interactive game (e.g., 'Fruit Slicing'). The patient engaged with the game while walking, diverting attention from conscious gait control to enhance unconscious proprioception. Gait disturbance training used a fixed sequence: a 5-min warm-up (0.5 m/s), followed by 10 min of game-based training (Fruit Slicing), with fruit appearance intervals standardized (10 sec initially, 5 sec after three weeks).[18] The training parameters were set as follows:

1. Gait speed: The initial speed was 0.5 to 0.8 m/s and was progressively increased to 0.8 to 1.2 m/s based on the patient's adaptation.
2. Game difficulty: At the starting level, fruit appears every 10 sec; as the training advances, the interval shortens to every 5 sec.
3. Training duration and frequency: The training lasted 10 to 15 min per session, with six sessions per week for six weeks.

**Outcomes**

All evaluations were conducted by the same rehabilitation physician, who was blinded to the patient group assignments. Assessments were performed at two time points: before treatment initiation and after six weeks of intervention. A three-dimensional (3D) gait analysis was performed using the Vicon Nexus 2.12 system (Vicon Motion Systems, Oxford, UK) with 8 cameras (100 Hz) and 16 reflective markers. The reflective markers were placed on key bony landmarks, including the anterior superior iliac spine, lateral malleolus and fifth metatarsal head. Participants completed five valid walking trials, each requiring at least three consecutive strides. Gait speed (m/s) and cadence (steps/min) were extracted by averaging data across all valid trials, with data processing conducted using Vicon software to ensure accuracy. Higher values for gait speed and cadence indicate better walking ability.

Balance function testing was performed using the Biodex Balance System SD (Biodex Medical Systems, Shirley, NY, USA) and the MOTOmed Viva 2 Intelligent Motor Training System.

**Primary outcomes**

Gait function was evaluated using the aforementioned 3D gait analysis system (Vicon Nexus version 2.12). Key metrics included the following:

1. Gait speed (m/s): higher values indicate better walking ability.
2. Cadence (steps/min): higher values reflect more efficient gait rhythm.

Static balance function was measured using the balance function testing and training system (Biodex Balance System SD) while maintaining a single-leg stance (eyes open). Key metrics included the following:

1. Movement length (mm): lower values indicate better postural stability.
2. Movement ellipse area ($mm^2$): smaller areas reflect improved balance control.

**Secondary outcome**

Dynamic balance function was assessed using the Star Excursion Balance Test (SEBT).[19] Participants stood barefoot on the non-injured limb and reached maximally with the injured limb in three directions (anterior, posteromedial, posterolateral). The results were normalized to leg length using the following formula:

Recorded score = (maximum reach distance / leg length) × 100%.

Higher percentages indicate better dynamic balance stability.

**Statistical analysis**

Study power analysis and sample size calculation were performed using the G*Power version 3.1 software (Heinrich-Heine University Düsseldorf, Düsseldorf, Germany). According to previous studies, BA combined with unconscious proprioception training yielded significant effects on functional recovery in patients with CAI, with an anticipated effect size (Cohen's d) of approximately 0.8 for between-group differences in SEBT scores, derived from the studies of acupuncture and proprioception interventions for CAI.[20,21] This effect size reflects the expected between-group difference post-intervention. With $\alpha = 0.05$ and $\beta = 0.20$ (power = 80%), a minimum of 37 patients per group was required. To account for potential dropouts, 40 patients per group (a total of 120) were enrolled.

Statistical analysis was performed using the IBM SPSS version 25.0 software (IBM Corp., Armonk, NY, USA). Continuous data were presented in mean ± standard deviation (SD) or median (min-max), while categorical data were presented in number and frequency. A two-way mixed analysis of variance (ANOVA) (group × time) was applied to assess the main effects (group: control, BA, CT; time: pre-treatment, post-treatment) and their interaction for all outcomes (gait speed, cadence, movement length, movement ellipse area, SEBT scores). Post-hoc comparisons were performed using the Bonferroni correction to adjust for multiple comparisons. Effect sizes and 95% confidence intervals (CIs) were calculated to indicate the magnitude and precision of differences. The *p*-values reported in the results refer to interaction effects, where a significant interaction indicates differential improvements across groups over time. A $p$ value of $< 0.05$ was considered statistically significant.

## RESULTS

### Patient groups

Table I presents the demographic and clinical baseline characteristics of the three groups (n = 40 per group). There was no statistically significant difference in age and sex among the groups ($p > 0.05$). In addition, disease duration and number of previous sprains were comparable among the groups ($p > 0.05$).

#### Evaluation using the three-dimensional gait analysis system

Before the six-week intervention, the three groups exhibited no significant differences in gait speed (control group: 0.69 ± 0.31 m/s; BA group: 0.73 ± 0.19 m/s; CT group: 0.68 ± 0.36 m/s) or cadence (control group: 62 ± 9 steps/min; BA group: 59 ± 15 steps/min; CT group: 60 ± 11 steps/min) ($p > 0.05$). Following the six-week intervention, all three groups showed significant improvements in gait speed and cadence compared to baseline ($p < 0.05$). Specifically, the control group's gait speed increased to 0.82 ± 0.22 m/s, the BA group's gait speed to 0.93 ± 0.19 m/s and the CT group's gait speed to 1.05 ± 0.26 m/s. Bonferroni post-hoc tests verified that the CT group exhibited greater improvements in gait speed ($p < 0.001$) and cadence (control group: 78 ± 11 steps/min; BA group: 83 ± 9 steps/min; CT group: 90 ± 13 steps/min) than the BA group ($p < 0.05$), with the BA group outperforming the control group ($p < 0.05$). The CT group's gait speed improvement had a large effect size (Cohen's d = 1.23, 95% CI: 0.88-1.58), exceeding the minimal clinically important difference (MCID) for CAI gait function. A two-way mixed ANOVA (group × time) revealed significant interaction effects for gait speed and cadence ($p < 0.05$). Bonferroni post-hoc tests confirmed that the CT group exhibited greater improvements than the BA group and control group ($p < 0.05$), with the

**TABLE I**
Comparison of general characteristics among the three groups

| | Control group (n = 40) | | BA group (n = 40) | | CT group (n = 40) | | | |
|---|---|---|---|---|---|---|---|---|
| | n | Mean ± SD | n | Mean ± SD | n | Mean ± SD | F/$\chi^2$ value | *p* |
| Mean age (year) | | 48.6 ± 6.8 | | 51.4 ± 7.1 | | 49.7 ± 6.3 | 1.75 | 0.18 |
| Sex | | | | | | | 2.14 | 0.34 |
| Male | 28 | | 31 | | 25 | | | |
| Female | 12 | | 9 | | 15 | | | |
| Mean disease duration (month) | | 3.7 ± 2.3 | | 4.0 ± 2.1 | | 3.9 ± 2.7 | 0.16 | 0.85 |
| Number of previous sprains (times) | | 22.1 ± 3.5 | | 21.8 ± 3.2 | | 22.3 ± 3.6 | 0.11 | 0.92 |

SD, standard deviation; BA, balance acupuncture; CT, combination therapy.

**TABLE II**
Comparison of gait speed and cadence among the three groups

| | Gait speed (m/s) | | Cadence (step/min) | | | | |
|---|---|---|---|---|---|---|---|
| | Before treatment | After treatment | Before treatment | After treatment | Interaction | Effect size | |
| | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD | *p* | (Cohen's d) | 95% CI |
| Control group (n = 40) | 0.69 ± 0.31 | 0.82 ± 0.22[a] | 62 ± 9 | 78 ± 11[a] | 0.0001 | 0.52 | 0.21-0.83 |
| BA group (n = 40) | 0.73 ± 0.19 | 0.93 ± 0.19[a,b] | 59 ± 15 | 83 ± 9[a,b] | 0.0001 | 0.87 | 0.54-1.20 |
| CT group (n = 40) | 0.68 ± 0.36 | 1.05 ± 0.26[a,b,c] | 60 ± 11 | 90 ± 13[a,b,c] | 0.0001 | 1.23 | 0.88-1.58 |

SD, standard deviation; BA, balance acupuncture; CT, combination therapy; CI, confidence interval; [a], Compared to pre-treatment levels, $p < 0.05$; [b], compared to the control group, $p < 0.05$; [c], compared to the BA group, $p < 0.05$. Effect sizes and 95% CIs are based on post-treatment between-group comparisons.

**TABLE III**
Comparison of balance function parameters among the three groups

| | Movement length (mm) | | Movement ellipse area (mm²) | | Interaction | Effect size | |
|---|---|---|---|---|---|---|---|
| | Before treatment | After treatment | Before treatment | After treatment | | | |
| | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD | $p$ | (Cohen's d) | 95% CI |
| Control group (n = 40) | 329.98 ± 58.16 | 271.63 ± 37.72[a] | 238.73 ± 105.12 | 198.14 ± 71.68[a] | 0.0003 | 0.48 | 0.17-0.79 |
| BA group (n = 40) | 335.41 ± 64.41 | 253.57 ± 46.34[a,b] | 246.54 ± 114.06 | 167.27 ± 65.13[a,b] | 0.0003 | 0.79 | 0.46-1.12 |
| CT group (n = 40) | 348.26 ± 43.53 | 236.11 ± 28.67[a,b,c] | 251.37 ± 103.43 | 135.62 ± 44.39[a,b,c] | 0.0003 | 1.15 | 0.80-1.50 |

SD, standard deviation; BA, balance acupuncture; CT, combination therapy; CI, confidence interval; [a], Compared to pre-treatment levels, $p < 0.05$; [b], compared to the control group, $p < 0.05$; [c], compared to the BA group, $p < 0.05$. Effect sizes and 95% CIs are based on post-treatment between-group comparisons.

BA group outperforming the control group ($p < 0.05$) (Table II).

### Evaluation using the balance function testing and training system

Before the intervention, there were no significant differences in movement length (control group: 329.98 ± 58.16 mm; BA group: 335.41 ± 64.41 mm; CT group: 348.26 ± 43.53 mm) or movement ellipse area (control group: 238.73 ± 105.12 mm²; BA group: 246.54 ± 114.06 mm²; CT group: 251.37 ± 103.43 mm²) among the three groups ($p > 0.05$). After six weeks, all groups showed significant reductions in both parameters ($p < 0.05$). The CT group had the smallest movement length (236.11 ± 28.67 mm) and movement ellipse area (135.62 ± 44.39 mm²), followed by the BA group (movement length: 253.57 ± 46.34 mm, movement ellipse area: 167.27 ± 65.13 mm²) and the control group (movement length: 271.63 ± 37.72 mm, movement ellipse area: 198.14 ± 71.68 mm²). Effect sizes for between-group differences in the movement ellipse area were large (CT *vs.* control: Cohen's d = 1.15, 95% CI: 0.80-1.50; CT *vs.* BA: Cohen's d = 0.79, 95% CI: 0.46-1.12), indicating clinically meaningful improvements in postural stability. Two-way mixed ANOVA indicated significant group × time interactions for movement length and movement ellipse area ($p < 0.05$). Post-hoc comparisons with Bonferroni correction showed the CT group had superior outcomes to the BA group and control group ($p < 0.05$), and the BA group improved more than the control group ($p < 0.05$) (Table III).

### Evaluation using the Star Excursion Balance Test

Baseline SEBT scores (anterior + posteromedial + posterolateral) were comparable among the three groups (control group: anterior = 65.83% ± 10.71%, posteromedial = 63.36% ± 8.15%, posterolateral = 63.45% ± 8.17%; BA group: anterior = 67.18% ± 9.19%, posteromedial = 62.32% ± 6.51%, posterolateral = 60.91% ± 7.39%; CT group: anterior = 64.96% ± 10.06%, posteromedial = 61.58% ± 7.84%, posterolateral = 63.21% ± 6.54%) (p>0.05). After six weeks, all SEBT scores increased (CT group: anterior = 85.83% ± 5.87%, posteromedial = 77.63% ± 7.26%, posterolateral = 76.42% ± 7.31%; BA group: anterior = 82.21% ± 6.96%, posteromedial = 74.25% ± 6.39%, posterolateral = 73.53% ± 6.27%; control group: anterior = 79.06% ± 7.68%, posteromedial = 70.59% ± 7.81%, posterolateral = 70.36% ± 5.25%). All within-group improvements were significant ($p < 0.05$), and Bonferroni post-hoc tests showed the CT group's SEBT score was significantly higher than those of the BA ($p < 0.001$) and control ($p < 0.001$) groups, with the BA group outperforming the control group ($p < 0.05$). The CT group's relative improvement in SEBT score exceeded the minimal important change (MIC) of 15% for dynamic balance in CAI, confirming clinical relevance (anterior: Cohen's d = 1.31, 95% CI: 0.96-1.66; posteromedial: Cohen's d = 1.27, 95% CI: 0.92-1.62; posterolateral: Cohen's d = 1.19, 95% CI: 0.84-1.54). A two-way mixed ANOVA demonstrated a significant interaction effect for SEBT scores ($p < 0.05$). Bonferroni post-hoc tests revealed that the CT group had higher scores than the BA group and control group ($p < 0.05$), with the BA group performing better than the control group ($p < 0.05$) (Table IV).

### Adverse reactions

No adverse reactions were reported in any of the 120 patients during the six-week intervention. Specifically, there were no incidents of falls, sports-related injuries (e.g., muscle strains, joint sprains), acupuncture-related adverse events (e.g., dizziness, bleeding, infection at the needling site) or fatigue-related discomfort. All patients completed the full intervention course with a

**TABLE IV**
Comparison of SEBT scores among the three groups

| | | Before treatment | After treatment | Interaction | Effect size | |
|---|---|---|---|---|---|---|
| Direction | n | Mean ± SD | Mean ± SD | $p$ | Cohen's d | 95% CI |
| Anterior | | | | | | |
| Control group | 40 | 65.83 ± 10.71 | 79.06 ± 7.68[a] | 0.0001 | 0.55 | 0.24-0.86 |
| BA group | 40 | 67.18 ± 9.19 | 82.21 ± 6.96[a,b] | 0.0001 | 0.89 | 0.56-1.22 |
| CT group | 40 | 64.96 ± 10.06 | 85.83 ± 5.87[a,b,c] | 0.0001 | 1.31 | 0.96-1.66 |
| Posteromedial | | | | | | |
| Control group | 40 | 63.36 ± 8.15 | 70.59 ± 7.81[a] | 0.0001 | 0.42 | 0.11-0.73 |
| BA group | 40 | 62.32 ± 6.51 | 74.25 ± 6.39[a,b] | 0.0001 | 0.85 | 0.52-1.18 |
| CT group | 40 | 61.58 ± 7.84 | 77.63 ± 7.26[a,b,c] | 0.0001 | 1.27 | 0.92-1.62 |
| Posterolateral | | | | | | |
| Control group | 40 | 63.45 ± 8.17 | 70.36 ± 5.25[a] | 0.0002 | 0.46 | 0.15-0.77 |
| BA group | 40 | 60.91 ± 7.39 | 73.53 ± 6.27[a,b] | 0.0002 | 0.82 | 0.49-1.15 |
| CT group | 40 | 63.21 ± 6.54 | 76.42 ± 7.31[a,b,c] | 0.0002 | 1.19 | 0.84-1.54 |

SEBT, Star Excursion Balance test; SD, standard deviation; BA, balance acupuncture; CT, combination therapy; CI, confidence interval; [a], Compared to pre-treatment levels, $p < 0.05$; [b], compared to the control group, $p < 0.05$; [c], compared to the BA group, $p < 0.05$. Effect sizes and 95% CIs are based on post-treatment between-group comparisons; P/F, p-value/F-value for group main effect.

compliance rate of ≥ 90% (control: 92.5%; BA group: 93.0%; CT group: 91.8%), verifying the safety and tolerability of the interventions.

## DISCUSSION

In the present study, we compared the efficacy of conventional rehabilitation alone, conventional rehabilitation combined with BA and conventional rehabilitation plus BA and unconscious proprioception training in CAI patients. Our study results showed that the CT group exhibited greater improvements in balance and gait function than those receiving conventional therapy or BA plus conventional therapy. These findings align with those of Wang et al.,[22] who reported that acupuncture improved balance; however, we extend this by demonstrating the additive benefits of unconscious training. In addition, based on these findings, we can speculate a potential synergistic association between BA and unconscious proprioceptive training, which may provide more comprehensive rehabilitation support for patients with CAI by targeting neuromodulation and motor control optimization. However, due to the unequal intervention doses (i.e., longer total session duration in the CT group) and lack of sham controls, causal inferences about the specific contributions of individual intervention components are limited.

In the current study, BA alone also improved gait and balance, consistent with the findings of a meta-analysis by Luan et al.[23] The aforementioned authors reported moderate effects of acupuncture on pain reduction and balance in CAI. However, our study further demonstrates that BA enhances not only static balance, but also dynamic gait parameters (e.g., cadence increased by 24 steps/min in the BA group), which can be attributed to the specific selection of the ankle pain point and cross-lateral needling, activating descending pain-inhibitory pathways that facilitate motor learning.[24]

The added value of unconscious proprioception training is also supported by Chai et al.,[25] who highlighted that reflexive neuromuscular control-targeted by our dual-task protocols-correlated with reduced ankle sprain recurrence. Unlike conscious training, our approach using music-distracted MOTOmed training enhanced automatic motor control by activating spinal reflex pathways and reducing cortical interference. However, not all studies support this mechanism. To illustrate, a systematic review by Han et al.[26] reported that the efficacy of unconscious/dual-task training for CAI was inconsistent across trials, with some reporting no significant improvements in dynamic balance. This may be due to differences in training intensity, distraction tasks or patient compliance. Our favorable findings add to this mixed evidence base, but still underscore the need for further research to identify which patient subgroups may benefit most from this training approach. Unconscious training improves adaptability to real-world scenarios.[27] Motor learning theory further supports this, as it emphasizes automatic control for real-world adaptability.[28]

Interpretation of outcomes related to unconscious proprioception training should take into account that there is currently no universally standardized definition of this term in the scientific literature. The concept encompasses a spectrum of interventions aimed at promoting automatic motor control, often through dual-task paradigms or distraction techniques that reduce conscious attention to movement.[29] In the present study, we operationally defined it as a structured, equipment-assisted dual-task protocol designed to shift focus away from conscious limb control. However, the specific methodologies labelled as 'unconscious' training can vary substantially across studies, differing in tasks, equipment and the degree of cognitive distraction. Therefore, the positive effects observed in the CT group should be interpreted primarily as evidence supporting the benefit of adding this specific, operationally defined dual-task regimen to the rehabilitation protocol. Claims about the efficacy of unconscious proprioception training as a broadly defined entity should be made with caution, and our mechanistic explanations regarding automatic motor control and spinal reflex pathways remain hypotheses that require validation through neurophysiological measures (e.g., electromyography, functional magnetic resonance imaging [MRI]) in future research. The findings highlight a promising direction but underscore the need for the field to develop more standardized nomenclature and protocols for interventions targeting non-conscious motor learning.

The observed improvements in key outcomes such as gait speed and SEBT not only reached statistical significance, but also exceeded established MIC thresholds,[30,31] verifying their clinical relevance. To depict, a 0.37-m/s increase in gait speed translates to better functional mobility in daily activities, such as crossing streets safely, and the 20.87% improvement in SEBT scores indicates reduced fall risk during dynamic tasks. Notably, the large effect size of CT for SEBT ($d = 1.31$, 95% CI: 0.90-1.72) further verifies the meaningful clinical benefits beyond statistical significance, reflecting the precision and magnitude of the observed improvements.

The substantial interaction effects could suggest a potential synergistic mechanism, although the contribution of longer intervention time cannot be excluded. The effects of BA on pain modulation are supported by a previous study.[32] It is hypothesized that BA may create a favorable neural environment by normalizing sensory input, allowing unconscious training to reinforce motor engrams more effectively. This is consistent with Hou et al.,[33] who noted that pain reduction (via acupuncture) enhances proprioceptive training efficacy. Our large ESs for CT (e.g., gait speed $d = 1.23$) exceed the MCID for CAI, verifying the study's clinical relevance.

The superiority of CT may be explained by (1) acupuncture reducing pain and thereby facilitating training, (2) unconscious training reinforcing automatic motor control, and (3) synergistic CNS remodeling. Balance acupuncture may stimulate the CNS and modulate neurotransmitter release, thereby enhancing proprioception and neuromuscular coordination. In addition, unconscious proprioception training activates reflexive neural pathways, improving automatic motor control.[34] The combined application of these interventions may promote CNS plasticity at multiple levels, leading to improved rehabilitation outcomes. The central regulatory effects of balance acupuncture may create a more favorable neural environment for unconscious proprioception training, facilitating more efficient activation of reflexive pathways.[35] This synergistic interaction may not only enhance neuromuscular control, but also reduce movement delays associated with conscious motor interference, resulting in smoother and more efficient motor execution.

Alternative explanations should also be considered when interpreting the findings. The longer duration and greater complexity of the CT may have led to enhanced patient engagement and motivation (the dose-response effect) rather than a true neurophysiological synergy between the specific components. Furthermore, the absence of blinding of participants and intervention providers increases the risk of performance and detection bias, which may have amplified the perceived treatment effects. Our mechanistic explanations, although grounded in the literature, still remain speculative due to the lack of physiological measures (e.g., electromyography, functional MRI) to directly validate the proposed neural mechanisms.

Despite the favorable findings, this study has several limitations that constrain the generalizability and causal interpretation of the results. First, unequal intervention doses among the groups may have influenced the outcomes. The CT group received a longer total intervention duration (85 min/session) than the BA (60 min) and control (60 min) groups, with reduced conventional therapy time offset by unconscious proprioception training. This imbalance means that the superior outcomes in the CT group may be partially attributed to greater overall intervention exposure rather than the specific synergistic effects of BA and unconscious training. Second, the lack of a sham control group limits the ability to isolate specific treatment effects from placebo or contextual effects. The absence of a sham acupuncture group or sham unconscious training group prevents us from distinguishing specific treatment effects from placebo or non-specific effects. This limits our ability to confirm that BA or unconscious proprioception training independently contributes to the observed improvements. Third, the short follow-up period and single-center design may have limited the assessment of long-term outcomes and reduced the generalizability of the findings. The six-week follow-up period does not allow assessment of whether the observed improvements are sustained in the long term, which is critical for evaluating rehabilitation outcomes in CAI. In addition, the single-center sample may lack diversity in patient characteristics, thereby limiting the generalizability of the findings to broader populations. Fourth, non-standardized definition of unconscious proprioception can be deemed. The concept of unconscious proprioception training lacks universal standardization in the literature,[12] and our protocol may differ from those of other studies. This reduces comparability and hinders the integration of our findings into the broader evidence base. Finally, although outcome assessors were blinded, participants and intervention providers were not, which may have introduced performance bias. Despite our efforts to standardize the intervention procedures, this bias cannot be fully excluded. Given the aforementioned limitations of the study, although this CT shows substantial efficacy, its clinical application still requires careful consideration. The 75-min session duration (30 min conventional rehabilitation + 15 min BA + 30 min unconscious proprioception training) represents a substantial time commitment that may pose challenges in routine clinical settings, where treatment sessions are typically limited to 30 to 45 min. Additionally, the requirement for specialized equipment and trained personnel to administer both BA and the structured dual-task protocol could limit widespread adoption, particularly in resource-constrained environments. These practical constraints suggest that the full protocol may be most appropriate for specialized rehabilitation centers or patients with persistent deficits who have failed to respond to standard care. Future research should explore abbreviated or modified versions of this combined approach, such as reducing session frequency while maintaining total intervention volume, or developing home-based components to enhance accessibility. Cost-effectiveness analyses comparing this intensive intervention against standard care would also provide valuable insights for clinical decision-making and resource allocation.

In conclusion, our study results indicate that combining BA and unconscious proprioception training with conventional rehabilitation can yield greater improvements in gait and balance function for patients with CAI than BA plus conventional rehabilitation or conventional rehabilitation alone. The added value of unconscious proprioception training suggests a potential synergistic association, likely stemming from BA's role in optimizing the neural environment and unconscious training's enhancement of automatic motor control. Based on these preliminary findings, the combined approach shows potential clinical value for targeted populations with CAI. However, future standardized trials incorporating balanced intervention exposure, sham controls, and long-term follow-up are required to validate the sustainability of the effects and to clarify the specific therapeutic contributions of each component.

**Data Sharing Statement:** The data that support the findings of this study are available from the corresponding author upon reasonable request.

**Author Contributions:** L.N., W.M.Z.H.W.: Conception and design; M.Q.: Administrative support; W.M.Y., S.K.,B.Y.L.: Provision of study materials or patients; J.X.W., L.J.,C.J.J: Collection and assembly of data; F.S.M., Z.H.W.,L.N.: Data analysis and interpretation.

**Conflict of Interest:** The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

**Funding:** This work was supported by Xuzhou Science and Technology Project (KC25082).

**AI Disclosure:** The authors declare that artificial intelligence (AI) tools were not used, or were used solely for language editing, and had no role in data analysis, interpretation, or the formulation of conclusions.

All scientific content, data interpretation, and conclusions are the sole responsibility of the authors. The authors further confirm that AI tools were not used to generate, fabricate, or 'hallucinate' references, and that all references have been carefully verified for accuracy.

## REFERENCES


1. Hardy A, Freiha K, Moussa MK, Valentin E, Rauline G, Alvino K, et al. Use of Ankle-GO to assess and predict return to sport after lateral ankle reconstruction for chronic ankle instability. Orthop J Sports Med 2025;13:23259671251322903. doi: 10.1177/23259671251322903.
2. Cruz-Montecinos C, Sanzana-Cuche R, Mendez-Rebolledo G. Regional muscle fiber conduction velocity of the fibularis longus in individuals with chronic ankle instability. J Anat 2025;247:375-84. doi: 10.1111/joa.14244.
3. Lopes R, Hong CC, Calder J, Kerkhoffs GMMJ. Risk factors for the recurrence of instability after operative treatment of chronic lateral ankle instability: A systematic review. J Exp Orthop 2025;12:e70214. doi: 10.1002/jeo2.70214.
4. Sagnard T, Picot B, Forestier N. Proprioceptive acuity, proprioceptive weighting and balance in individuals with chronic ankle instability. Gait Posture 2025;119:178-84. doi: 10.1016/j.gaitpost.2025.03.006.
5. Mei N, Jiang Z, Kurokawa H, Ueno Y, Liu H, Zou J, et al. Recurrent sprains of chronic ankle instability with chronic syndesmotic injury are primarily correlated with plantarflexion instability and multisensory deficits. Phys Ther Sport 2025;73:77-85. doi: 10.1016/j.ptsp.2025.03.004.
6. McWethy M, Norte GE, Bazett-Jones DM, Murray AM, Rush JL. Cognitive-motor dual-task performance of the landing error scoring system. J Athl Train 2025;60:21-8. doi: 10.4085/1062-6050-0558.23.
7. Chang S, Tan Y, Cheng L, Zhou L, Wang B, Liu H. Effect of strength training with additional acupuncture on balance, ankle sensation, and isokinetic muscle strength in chronic ankle instability among college students. Front Physiol 2024;15:1324924. doi: 10.3389/fphys.2024.1324924.
8. Jamali Dastjerdi M, Azadvari M, Kordafshari G, Zhao BX, Adel-Mehraban MS, Alipour R, et al. Comparative efficacy of acupuncture, venesection, and physical therapy on chronic low back pain outcomes: A randomized clinical trial. Ann Med Surg (Lond) 2024;86:2729-38. doi: 10.1097/MS9.0000000000001944.
9. Wang WY. Wang Wenyuan's Balance Acupuncture for Pain in the Neck, Shoulder, Low Back and Legs. Beijing: China Press of Traditional Chinese Medicine; 2010. p. 58-9.
10. Aicale R, Maffulli N. Rotational ankle instability: A current concept review. J Orthop Surg (Hong Kong) 2023;31:10225536231182347. doi: 10.1177/10225536231182347.
11. Ari MC, Yazgan NK, Kural C, Baca E. The usefulness of tuning-fork-assisted vibration sensation as a proprioceptive measurement method in cases of acute anterior talofibular ligament rupture: A single-center study. Ulus Travma Acil Cerrahi Derg 2025;31:1203-11. doi: 10.14744/tjtes.2025.48242.
12. Portugal JM, Martins Rodrigues I, Sarro KJ. Dancers with chronic ankle instability have different regional plantar force during single-leg jump landing. J Dance Med Sci 2026;30:59-64. doi: 10.1177/1089313X251325284.
13. Liu YD, Wan XL. Comparison of effects of proprioceptive neuromuscular facilitation and whole body vibration training on functional ankle instability. Chin J Rehabil Theory Pract 2022;28:776-82.
14. Gribble PA, Delahunt E, Bleakley CM, Caulfield B, Docherty CL, Fong DT, et al. Selection criteria for patients with chronic ankle instability in controlled research: A position statement of the International Ankle Consortium. J Athl Train 2014;49:121-7. doi: 10.4085/1062-6050-49.1.14.
15. Mirshahi M, Halabchi F, Golbakhsh M, Saadat S. Reliability and recalibration of the persian version of cumberland ankle instability tool cut-off score in athletes with functional ankle instability. Adv J Emerg Med 2019;3:e26. doi: 10.22114/ajem.v0i0.180.
16. Alahmari KA, Kakaraparthi VN, Reddy RS, Silvian P, Tedla JS, Rengaramanujam K, et al. Combined effects of strengthening and proprioceptive training on stability, balance, and proprioception among subjects with chronic ankle instability in different age groups: Evaluation of clinical outcome measures. Indian J Orthop 2020;55:199-208. doi: 10.1007/s43465-020-00192-6.
17. Lin CW, Jankaew A, Lin CF. Physical therapy intervention effects on alteration of spinal excitability in patients with chronic ankle instability: A systematic review and meta-analysis. Sports Health 2025;17:394-403. doi: 10.1177/19417381241253248.
18. Tan F, Guney-Deniz H, Harput G, Ulusoy B, Dönmez G, Nyland J, et al. Altered ankle muscle activation at 2-year post achilles tendon repair: An age, gender, and activity level-matched comparison with healthy subjects. J Sport Rehabil 2023;32:305-14. doi: 10.1123/jsr.2022-0064.
19. Sadaak MM, AbdElMageed SF, Ibrahim MM. Effect of aquatic versus conventional physical therapy program on ankle sprain grade III in elite athletes: randomized controlled trial. J Orthop Surg Res 2024;19:400. doi: 10.1186/s13018-024-04855-0.
20. Liu N, Zhang M, Feng SM, Bi YL, Zhai HW, Meng Q. Effect of hip strategy-based motion control training on walking function restoration after ankle joint injury. Jt Dis Relat Surg 2024;35:54-61. doi: 10.52312/jdrs.2023.1277.
21. İğde N, Kurt A, Aycan OE, Arslan MC, Bıyıklı T. The impact of proximal fibula resection on foot and ankle biomechanics: A radiological and pedobarographic evaluation. Jt Dis Relat Surg 2025;36:373-82. doi: 10.52312/jdrs.2025.2185.
22. Wang YN, Zhang T, Liu YM, et al. Validity and reliability of Star Excursion Balance Test for dynamic balance assessment in stroke patients. Chin J Rehabil Theory Pract 2021;27:604-8.
23. Luan L, Zhu M, Adams R, Witchalls J, Pranata A, Han J. 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. Complement Ther Med 2023;77:102983. doi: 10.1016/j.ctim.2023.102983.
24. Patel M, Urits I, Kaye AD, Viswanath O. The role of acupuncture in the treatment of chronic pain. Best Pract Res Clin Anaesthesiol 2020;34:603-16. doi: 10.1016/j.bpa.2020.08.005.
25. Chai L, Sun X, Huang Q, Huang T, Guo X, Liu H. Cortical changes of dual cognitive-task balance training in patients with chronic ankle instability: A randomized trial. J Athl Train 2024;59:1077-88. doi: 10.4085/1062-6050-0463.23.
26. Han J, Luan L, Adams R, Witchalls J, Newman P, Tirosh O, et al. Can therapeutic exercises improve proprioception in

chronic ankle instability? A systematic review and network meta-analysis. Arch Phys Med Rehabil 2022;103:2232-44. doi: 10.1016/j.apmr.2022.04.007.
27. Worden TA, Vallis LA. Examining transfer effects of dual-task training protocols for a complex locomotor task. J Mot Behav 2018;50:177-93. doi: 10.1080/00222895.2017.1327409.
28. Winterbottom L, Nilsen DM. Motor learning following stroke: Mechanisms of learning and techniques to augment neuroplasticity. Phys Med Rehabil Clin N Am 2024;35:277-91. doi: 10.1016/j.pmr.2023.06.004.
29. Picot B, Maricot A, Fourchet F, Gokeler A, Tassignon B, Lopes R, et al. Targeting visual-sensory and cognitive impairments following lateral ankle sprains: A practical framework for functional assessment across the return-to-sport continuum. Part 2: From theory to practice: Recommendations for optimizing return to sport after lateral ankle sprains using cognitive and visual-sensory assessments. Front Sports Act Living 2025;7:1702858. doi: 10.3389/fspor.2025.1702858.
30. Ou L, Meng Y, Chen Z, Zhang T, Kong D, Xu D, et al. Evidence of Chinese herbal fumigation for knee osteoarthritis: A protocol for systematic review and meta-analysis. Medicine (Baltimore) 2021;100:e24532. doi: 10.1097/MD.0000000000024532.
31. Prudêncio DA, Maffulli N, Migliorini F, Serafim TT, Nunes LF, Sanada LS, et al. Eccentric exercise is more effective than other exercises in the treatment of mid-portion Achilles tendinopathy: Systematic review and meta-analysis. BMC Sports Sci Med Rehabil 2023;15:9. doi: 10.1186/s13102-023-00618-2.
32. Trinh K, Belski N, Zhou F, Kuhad A, Luk D, Youn E. The efficacy of acupuncture on foot and ankle for pain intensity, functional status, and general quality of life in adults: A systematic review. Med Acupunct 2021;33:386-95. doi: 10.1089/acu.2021.0006.
33. Hou Z, Ren S, Hu Y, Jiao C, Guo Q, Li N, et al. Comparison of subjective and biomechanical outcomes between proprioceptive training and modified Broström-Gould surgery for chronic ankle instability: A randomized controlled trial. Orthop J Sports Med 2024;12:23259671241274138. doi: 10.1177/23259671241274138.
34. Meng F, Li A, You Y, Xie C. Motor expertise modulates unconscious rather than conscious executive control. PeerJ 2019;7:e6387. doi: 10.7717/peerj.6387.
35. Su N, Cai P, Dou Z, Yin X, Xu H, He J, et al. Brain nuclei and neural circuits in neuropathic pain and brain modulation mechanisms of acupuncture: A review on animal-based experimental research. Front Neurosci 2023;17:1243231. doi: 10.3389/fnins.2023.1243231.