

Comparison of Recent Studies on Rehabilitation of Chronic Ankle Instability: A Systematic Review

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Background There are many factors contributing to chronic ankle instability (CAI), but recently it has been reported that dynamic balance, peroneal reaction time, and eversion strength deficiency are highly related.

Purpose The purpose of this study was to find out whether the contributing factors of ankle instability were used in rehabilitation interventions and, if so, whether they were effective.

Study design Systematic review

Methods Relevant health databases, such as PubMed, MEDLINE, CINAHL and ScienceDirect, were searched. Systematic reviews were included if they fit the research question, and they were clearly defined by the search strategy criteria.

Results A total of 58 articles were retrieved and 19 articles fulfilled inclusion criteria. In duplicate counts, dynamic balance training (DBT) was used as an intervention in 15 studies, and strength training (ST) was used in 4 studies. There were also mixed forms of intervention that made it difficult to divide exercise methods.

Conclusions DBT and ST improved the ankle strength, balance, functional performance, and self-reported function of CAI patients. There was limited evidence that either DBT or ST was more effective in improving function in CAI patients.

Key words Chronic ankle instability; Dynamic balance; Rehabilitation; Strength; Vibration training.

JMST

2020; 4(2): 41-50

Published Online

Dec 31, 2020

pISSN 2635-8573

eISSN 2635-8581



Article History

Received 17 Oct 2020

Revised 3 Nov 2020

(1st)

Revised 9 Nov 2020

(2nd)

Accepted 9 Nov 2020

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INTRODUCTION

Ankle sprains occur very frequently during daily and sports activities.¹⁻³ Chronic ankle instability (CAI) is a common result of an ankle sprain.^{4,5} About 73% of individuals who have experienced ankle sprain injuries have recurrent episodes, of which 59% report long-term disability.¹ The common symptoms of CAI include feeling of instability, sensation of giving way, and subsequent sprains.^{1,6,7} Additionally, patients with CAI often have defects in functional performance, proprioception, and strength.⁹ The sequential development of CAI has negative health effects, including poor quality of life and early onset osteoarthritis.⁷

Studies before the International Ankle Consortium (IAC) published the standard inclusion criteria for CAI in 2014

have differences in methodological quality, outcome measurement method, and criteria for selecting participants.^{7,8,10} Standard inclusion criteria approved by IAC for enrolling patients with heterogeneous conditions of CAI in controlled studies are as follows: 1) a history of at least 1 significant ankle sprain, and the initial sprain must have occurred at least 12 months prior to study enrollment, 2) a history of the previously injured ankle joint "giving way," recurrently spraining, and/or having "feelings of instability," and self-reported ankle instability should be confirmed using the relevant cutoff score from a specific questionnaire validated for ankle instability [ankle instability instrument (AII)-answer "yes" to at least 5 yes/no questions, Cumberland ankle instability tool (CAIT) < 24, identification of functional ankle instability (IdFAI) > 11], 3) a general self-

reported foot and ankle function questionnaire is recommended to describe the level of disability [foot and ankle ability measure (FAAM) < 90% of activities of daily living (ADL) scale, <80% of sport scale, foot and ankle outcome score (FAOS) < 75% in 3 or more categories].¹⁰ It was recommended to exclude any patients with acute damage to the musculoskeletal structure in other joints of the lower extremity (i.e. sprains, fractures), which impacted joint integrity and function, and who have had at least one day of discontinuation of desired physical activity.¹⁰ Patients with a history of previous surgery for both limb musculoskeletal structures of the lower extremities, such as bones, joint structures, and nerves, were also recommended to be excluded to minimize heterogeneity of chronic ankle instability.¹⁰ Despite the IAC's recommendations, it was unclear whether the results of previous systematic reviews accurately reflect the CAI population, according to a 2016 study by Tompson et al.⁷ Subjects' inclusion criteria varied in many previous studies comparing such things as the characteristics of the CAI population and treatment effects. Additionally, inconsistent terminology and multiple operational definitions of CAI were widespread across the literature.^{7,8}

There are many factors contributing to CAI that can cause disorders, but this condition is more heterogeneous than many perceive.¹⁰ Knowledge of CAI and the factors contributing to its development is critical to developing targeted interventions and preventing long-term symptoms.⁷ A current review reported strong evidence that contributing factors to CAI were dynamic balance, peroneal reaction time, and eversion strength deficits.⁷ Impaired dynamic balance, delayed peroneal reaction time, and lack of eversion muscle strength make the ankle joint unable to cope with the inversion sprain. Common individual rehabilitation exercises for CAI patients are balance training using unstable support surfaces and strengthening using elastic bands.¹¹ Strengthening intervention using an elastic band helps increase muscle strength and joint position sense, and exercise using an unstable support surface helps reduce muscle latency onset and postural sway.¹¹ However, studies involving CAI patients are rare or have limited evidence.^{7,11}

Therefore, the purpose of this study was to investigate the results of recent CAI rehabilitation studies with strong contributing factors and whether CAI participants meet the criteria according to IAC recommendations.

METHOD

The protocol of this systematic review was developed using the framework outlined in the guidelines provided by the PRISMA (preferred reporting items for systematic

review and meta-analyses) statement.¹² The risk of bias assessment was conducted using a modified version of the quality index checklist.

Search strategy

The primary search was conducted on PubMed, MEDLINE, CINAHL and ScienceDirect. The search strategy was identical for all databases using 'chronic ankle instability AND rehabilitation' as the search terms with filters applied for full text, randomized controlled trial, and within the last 5 years. Selection criteria were as follows: 1) the study compared a group of participants with CAI to a control group, 2) it compared the effects before and after intervention using dynamic balance, peroneal reaction time or eversion strengthening, 3) the outcome variable were related to the ankle instability score.

Assessment of risk of bias

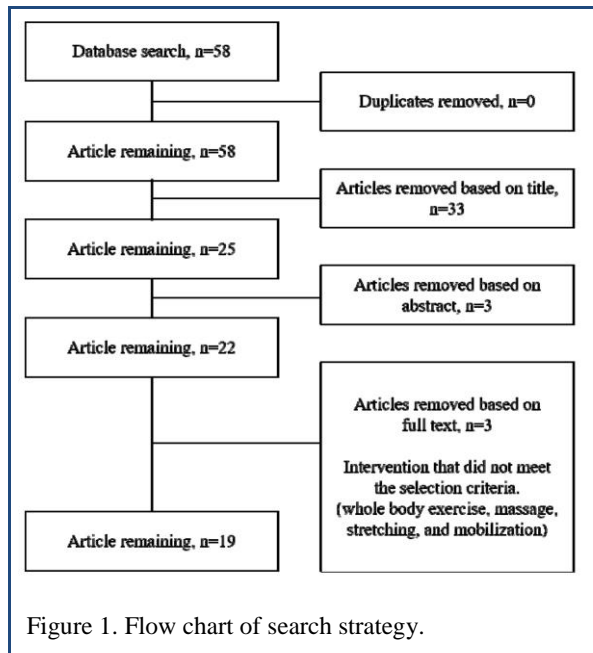
Risk of bias in the included studies was determined using the Cochrane Collaboration risk of bias assessment tool.¹³ A judgment that the risk of bias was low, unclear, or high was provided along with a statement of evidence for the cause of bias for each study. The causes of the biases considered were random sequence generation, assignment concealment, blinding of participants and staff, blinding of outcome evaluation, and incomplete outcome data.¹³

Data analysis

As the selected studies lacked study homogeneity, such as intervention type, duration, and major outcome factors, data pooling for meta-analysis was not possible.

RESULTS

A total of 58 articles were retrieved. After the title and abstract review, 22 articles underwent full-text review. Following a complementary search and assessment of full manuscripts, 19 articles fulfilled the inclusion criteria (Figure 1). Summaries of the studies were shown in Table 1. All selected studies were conducted in participants who met the IAC recommendations for CAI.^{11,14-31} Allowing duplicate counts of intervention type resulted in 15 articles using dynamic balance training (DBT)^{11,14-27}, 4 articles using strength training (ST)^{11,14-16}, and 4 articles using mixed type.²⁸⁻³¹ The mixed interventions included functional activity, range of motion (ROM), strength, balance, and neuromuscular training.²⁸⁻³¹ There were 12 studies comparing the effects of each exercise type before and after exercise.^{11,14-16,20-22,24-27,31} Six studies were conducted on the effects of



whole-body vibration, sensory targeted ankle rehabilitation strategies, and unstable surfaces.^{16-18,22,27-28} There was one study comparing the effects of exercise on functionally unstable ankles and functionally stable ankles.²⁹ All studies described a method of random allocation and did random sequence generation (low risk of bias).^{11,14-31} In most studies, except for one, outcome assessment was double blinded and complete outcome data was provided (low risk of bias).^{11,14-31}

DISCUSSION

The purpose of this study was to systematically review and evaluate the effectiveness of training reflecting the factors contributing to the development of CAI and whether recent studies on CAI selected participants that met the recommendations of the IAC. In all selected studies, the subject selection criteria met IAC recommendations.^{11,14-31} The findings of the current review indicated that the intervention of recent studies are mainly concerned with dynamic stability, and it is rare to include reaction time and eversion strength.^{11,13-26} DBT improved the ankle strength, balance, functional performance, and self-reported function of CAI patients (Table 1). In ST groups, all of these factors improved (Table 1). However, because strengthening exercise protocols included dorsiflexion, plantar flexion, inversion and eversion, the relevance to eversion strength was not clear.^{11,13-15} There was limited evidence whether DBT or ST was more effective in improving function in CAI patients.^{11,14-16} There was also controversy about the effectiveness of using an unstable support surface, vibration, or

sensory-targeted ankle rehabilitation strategies (mobilization, massage, and stretching) in the balance exercise protocol.^{17-19,22,23,31}

In the selected studies, CAIT, FAAM, global rating of function (GRF), star excursion balance test (SEBT), foot lift test, hop test, kinetics, and kinematic were used dependent variables.^{11, 14-18,20,22-24,26-31} As an instability measurement, SEBT, foot lift test, hop test, kinetics, and kinematics provided valid, objective, and quantifiable data to evaluate the balance ability of the ankle joint. CAIT, FAAM, and GRF as subjective data were also used in a validated ankle instability specific questionnaire to confirm self-reported ankle instability.¹⁰ The subjective ‘feelings of instability’ are also important factors that limit patients’ functional activity and reduce their quality of life.¹¹ The CAI populations feel that an unstable ankle joint is usually associated with the fear of sustaining an acute ligament sprain during ADL and sporting activities.¹⁰ Health care clinicians should aim to reduce fear-avoidance as well as symptoms and dysfunction to improve the functioning of CAI populations. According to the results of this study, several weeks of DBT, ST, and progressively therapeutic exercise will help improve balance, strength, and self-efficacy in CAI patients.^{11,14-31} Previous studies have shown that a significant number of CAI patients are experiencing recurrent episodes. According to a study by Wright et al., about 43% of participants maintained a decrease in ‘giving way (the regular occurrence of uncontrolled and unpredictable episodes of excessive inversion of the rear foot)’ after 6 months post-intervention.¹⁴ However, as most of the selected studies measured intervention effectiveness immediately after exercise, the long-term effects were not known for certain.^{11,5-17,19,20,22-29,31}

The selected studies were not homogeneous in exercise method, intervention period, and outcome variables, excluding the criteria for selecting CAI participants. Therefore, there is a limitation as comparison using statistical analysis cannot be performed. In addition, in some studies, the similarity between the measurement method and the DBT method used as an outcome variable could not be completely excluded. Therefore, in future studies, it will be necessary to evaluate methodological bias and meta-analysis of articles with research homogeneity.

CONCLUSIONS

This study found that DBT, ST, and therapeutic exercise improved the ankle strength, balance, functional performance, and self-reported function of CAI patients. There is limited evidence on which exercise is most effective in improving function in CAI patients.

Table 1. Summary of articles

| Type | Intervention | | Author | Inclusion/ exclusion criteria | Outcome variable | Main findings |
|------------------------|---|---|-----------------------------|-------------------------------------|---|---|
| | Specificity | Protocol | | | | |
| DBT* or ST† | 2 subgroups: 1. Wobble-board balance training; a single-leg stance exercise with clockwise and counter-clockwise rotations 2. Strength-training using Theraband; plantarflexion, dorsiflexion, inversion and eversion | 3 times each week, for 4weeks | Wright et al. ¹¹ | Mentioned Met IAC‡ | CAIT§ FAAM FAAM - ADL¶ and sport SF-36** GRF†† Foot lift test Time-in-balance SEBT‡‡-posterior medial direction Figure of 8 hop test Side hop test | A single exercise can reduce symptoms and improve clinical test performance. Limited evidence indicates that wobble-board balance training was more effective than strength-training. |
| | 2 subgroups: Further study of Wright et al. ¹¹ at 6 month post-intervention, | 3 times each week, for 4weeks | Wright et al. ¹⁴ | Mentioned Met IAC | CAIT FAAM FAAM - ADL and sport SF-36 GRF Foot lift test Time-in-balance SEBT-posterior medial direction Figure of 8 hop test Side hop test | Some improvements were maintained, but not all. |
| DBT, ST, or Control | 3 subgroups: 1. Balance-Training; 5 dynamic activities to challenge efficient recovery of single-limb balance 2. Strength-Training; resistance-band protocols (dorsiflexion, inversion, and eversion) and heel raises with a slow-reversal proprioceptive neuromuscular facilitation (PNF) technique 3. Control Group; 20-minute bicycle workout with consistent mild to moderate resistance | 20 minutes, 3 times each week, for 6 weeks. | Hall et al. ¹⁵ | Mentioned Met IAC | Isokinetic strength SEBT-anterior, posterolateral, and posteromedial The Balance Error Scoring System: double-legged stance, single-legged stance, and tandem stance Side hop test. | Both the DBT and ST groups improved strength, balance, and functional performance, while the control group did not improve. |

Table 1. Continued

| Type | Intervention | | Author | Inclusion/ exclusion criteria | Outcome variable | Main findings |
|--|--|--|--------------------------------|-------------------------------------|--|---|
| | Specificity | Protocol | | | | |
| DBT, ST, or Control | 3 subgroups: 1. Balance training; 5 dynamic activities to challenge efficient recovery of single-limb balance 2. Strength training; resistance-band protocols(dorsiflexion, inversion, and eversion) and heel raises with a slow-reversal PNF technique 3. Control Group; 20- minute bicycle workout with consistent mild to moderate resistance | 20 minutes, 3 times each week, for 6 weeks. | Hall et al. ¹⁶ | Mentioned Met IAC | Disablement in the Physically Active Scale, the Fear- Avoidance Beliefs Questionnaire, FAAM FAAM - ADL and sport VAS ^{§§} | Global and regional health- related quality of life was improved in all 3 groups. |
| DBT or control | 2 subgroups: 1. Wobble-board balance training; a single-leg stance exercise with clockwise and counter-clockwise rotations, difficulty of training progressed (height of each level increased by half inch) 2. Control; no intervention | 3 times each week, for 4 weeks | Linens et al. ¹⁷ | Mentioned Met IAC | Foot lift test Time-in-balance Test SEBT Side hop test | Wobble board training significantly improved static balance. |
| DBT with or without STARS | 2 subgroup: 1. Balance training progressively 2. Balance training with STARS; 5 minutes, calf stretching, plantar massage, ankle joint mobilizations, and ankle joint traction before each balance training session | 20 minutes, 3 times each week, for 4 weeks | Burcal et al. ¹⁸ | Mentioned Met IAC | Self-assessed disability: 24- hour, 1-week, 1- month after the intervention SEBT: 24-hour and 1-week after the intervention Static single limb stance (time-to- boundary of center of pressure); 24-hour and 1-week after the intervention MCID ^{¶¶} MDC ^{***} | Both groups demonstrated improvements in all outcome categories. Only balance training with STARS group exceeded MDC for static balance outcomes. |

Table 1. Continued

| Type | Intervention | | Author | Inclusion/ exclusion criteria | Outcome variable | Main findings |
|---|--|--|---|-------------------------------------|--|---|
| | Specificity | Protocol | | | | |
| DBT with or without vibration Control | 3 subgroups: Progressed balance exercise 1. Vibration group; trained with BOSU on an Excel , or Pro vibration platform 2. Non-vibration group; trained with the BOSU on the floor 3. Control; no intervention | 3 times each week, for 6 weeks | Sierra- Guzmán et al. ¹⁹ | Mentioned Met IAC | Muscle reaction times Electrical muscle activity | No significant changes in electrical activity. Only in the vibration group, the response time of peroneus brevis, peroneus longus, and tibialis anterior muscle was significantly improved. |
| | 3 subgroups: progressed balance exercise 1 Vibration group; trained with BOSU on an Excel Pro vibration platform 2.Non-vibration group; trained with the BOSU on the floor 3. Control; no intervention | 3 times each week, for 6 weeks | Sierra- Guzmán et al. ²⁰ | Mentioned Met IAC | Biodex Balance System; overall stability index, anterior-posterior stability index, medial-lateral stability index SEBT | Whole body vibration training on an unstable surface improved balance in participants with CAI ^{†††} . Both training groups performed better on the SEBT. Only the vibration group performed better the Biodex Balance System. |
| DBT | 2 subgroups: 1. 1 minute of balance board training daily for 3 weeks 2. The same training for 6 weeks | 1 minute, daily, for 3 weeks or 6 weeks | Steinberg et al. ²¹ | Mentioned Met IAC | Active ankle inversion movement discrimination ability: immediately, 3- week, and 4week after the intervention | Ankle discrimination acuity scores improved over time for both groups. A significantly faster rate of improvement in ankle discrimination ability score was found for dancers with previous ankle sprain during the last 2 years. |
| | 2 subgroups: 1. Traditional single-limb balance training; progressive single-limb balance 2. Progressive dynamic balance training: hop-to- stabilization balance | 3 times each week, for 4weeks | Anguish et al. ²² | Mentioned Met IAC | FAAM FAAM - ADL and sport SEBT Joint position sense | Both programs improved self-reported function, dynamic postural control, and joint position sense. Which type of balance training has the greatest effect on improving postural control and function is unknown. |
| | 2 subgroups: 1. A single-leg stance exercise with active power plate 2. Control with inactive power plate | 2 days | Rendos et al. ²³ | Mentioned Met IAC | Static balance: center of pressure displacement SEBT | Static balance improved in both CAI and healthy participants. Whole body vibration training does not acutely improve static or dynamic balance. |
| | 2 subgroups: 1. Progressive balance training with BAPS board 2. Control; no intervention | 3 times each week, for 4 weeks | Cain et al. ²⁴ | Mentioned Met IAC | Time-in-balance test Foot lift test, SEBT Side hop test | The balance training group improved performance on all measures at posttest, whereas the control group did not. |

Table 1. Continued

| Type | Intervention | | Author | Inclusion/ exclusion criteria | Outcome variable | Main findings |
|-------------------|---|--------------------------------------|------------------------------------|-------------------------------------|---|---|
| | Specificity | Protocol | | | | |
| DBT | 2 subgroups: 1. Balance training: kicking task with progressively altered conditions 2. Control; no intervention | 30 minutes | Conceição et al. ²⁵ | Mentioned Met IAC | Center of pressure displacement Anticipatory postural adjustments Compensatory postural adjustments | Postural sway increased during the ball-kicking activity and decreased during a static task in individuals with chronic ankle instability. Tibialis anterior and peroneus longus activity increased after the kick in the balance- perturbation–training group. |
| | 2 subgroups: 1. Progressive hop stabilization training; figure 8, square shape, zigzag pattern, forward- backward, side to side, and forward hop 2. Control; no intervention | 3 times each week, for 6 weeks | Minoonejad et al. ²⁶ | Mentioned Met IAC | Preparatory and reactive muscle activation (muscle onset time) FAAM FAAM- sport CAIT FAOC ^{***} | All factors improved in the hop stabilization training group compared to the control group. |
| | 2 subgroups: 1. Progressed hop stabilization training 2. Control; no intervention | 3 times each week, for 6 weeks | Ardakani et al. ²⁷ | Mentioned Met IAC | Kinematics and kinetics during a single-limb jump landing FAAM FAAM- sport CAIT FAOC | Hop-stabilization program resulted in improved biomechanics and decreased ground reaction forces during a single-limb jump landing. |
| Mixed exercise | 2 subgroups: 1. Progressive rehabilitation program with destabilization devices; functional activity, ROM ^{§§§} , strength, and balance exercises 2. Control; same type exercise without devices | 3 times each week, for 4 weeks | Donovan et al. ²⁸ | Mentioned Met IAC | Kinematics, Kinetics Surface electromyography activity. | Ankle destabilization devices caused an increase in dorsiflexion ROM during mid to late stance during gait after rehabilitation, which may contribute to an increase in ankle joint stability. Ankle destabilization devices during balance and functional exercises did not alter frontal plane kinematics or kinetics of the ankle, knee and hip joint. |
| | 2 subgroups: 1. Progressive rehabilitation program with destabilization devices; functional activity, ROM, strength, and balance exercises 2. Control; same type exercise without devices | 3 times each week, for 4 weeks | Donovan et al. ²⁹ | Mentioned Met IAC | Ankle ROM Strength SEBT Static balance (center of pressure on a force plate) | Both groups had large improvements in self- reported function and ankle strength. No differences between the no-device and device groups for any measure. |

Table 1. Continued

| Type | Intervention | | Author | Inclusion/ exclusion criteria | Outcome variable | Main findings |
|----------------|---|--|---------------------------|-------------------------------------|---|--|
| | Specificity | Protocol | | | | |
| Mixed exercise | 2 subgroups | 60 minutes, 5 times each week, for 6 weeks | Kim et al. ³⁰ | Mentioned Met IAC | Kinematic data during walking, running, and landing; 6-week and 24-weeks after the intervention | A relatively inverted ankle position during walking and running in functionally unstable ankle group. Neuromuscular training had an immediate effect on changing ankle orientation toward a less everted direction during walking and running as well as jump landing. The changed ankle kinematics seemed to persist during jump, landing but not during walking and running. |
| | 2 subgroups: 1. Therapeutic exercise on sea sand 2. Self-management at home on a firm surface | 60 minutes, 5 times for a week | Shin et al. ³¹ | Mentioned Met IAC | Static balance (center of pressure on a force plate) VAS; pain and fatigue | Therapeutic exercise on sea sand effectively improved balance and decreased pain and fatigue. |

* DBT, dynamic balance training; † ST, strength-training; ‡ IAC, the international ankle consortium; § CAIT, Cumberland ankle instability tool; || FAAM, foot and ankle ability measure; ¶ ADL, activities of daily living; ** SF-36, short-form 36; †† GRF, global rating of function; †† SEBT, star excursion balance test; §§ VAS, visual analog scale; ||| STARS, sensory-targeted ankle rehabilitation strategies; ¶¶ MCID, minimal clinically important difference; *** MDC, minimal detectable change; ††† CAI, chronic ankle instability; †††† FAOC, foot and ankle outcome score; §§§ ROM, range of motion.

Key Points

Question Is the rehabilitation intervention of chronic ankle instability focused on the contributing factor of instability and the treatment effect?

Findings Dynamic balance training was used in research on chronic ankle instability (CAI). Dynamic balance and strength training improved the ankle strength, balance, functional performance, and self-reported function of CAI patients.

Meaning It could be applied to the development of management and intervention programs for the CAI population.

Article information

Conflict of Interest Disclosures: None.

Funding/Support: None.

Acknowledgment: None.

Ethic Approval: This manuscript does not require IRB/IACUC approval because there are no human and animal participants.

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