Volume 4, Issue 5, 2026

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

EFFECT OF A STRUCTURED PROGRESSIVE BALANCE TRAINING PROGRAM ON DYNAMIC POSTURAL CONTROL AND FUNCTIONAL OUTCOMES IN ATHLETES WITH CHRONIC ANKLE INSTABILITY: A RANDOMIZED CONTROLLED TRIAL

Mohammad Jawad Khan[1], Kamran Akbar[2], Arsalan Rasool[3], Farhan Shah[4],
Saira Muzaffar Shah[5], Hazrat Bilal[*6], Farhad Gul[7]

[1]Master of Musculoskeletal Physical Therapy, Physical Therapist, Khyber Medical University, Peshawar, Pakistan
[2]MS-PT MSK, Institute of Physical Medicine and Rehabilitation (KMU), Visiting Lecturer (KMU)
[3]Lecturer MPhil Prosthetics & Orthotics, Khyber Medical University, Peshawar
[4]P&O Lecturer KMU Peshawar, PHD Rehabilitation Sciences M Phil (Public Health) PGD (Assistive technology) BS (Prosthetics and orthotics)
[5]Ms-NMPT, Lecturer - Shaheed Zulfiqar Ali Bhutto Medical College
*[*6]Lecturer DPT, MSPT, CHR, CHPE, PhD Scholar, Institute of Physical Medicine and Rehabilitation, Khyber Medical University, Peshawar*
[7]Center Manager DPT, Master in Health & Physical Education, Registered Member of World Taekwondo Federation. CPRC (Center) Helping Hand, Pakistan

[1]jawadkhan.kmu@gmail.com, [2]kamranakbar.pt@gmail.com, [3]arsalanrkgul@gmail.com,
[4]syedfarhanshah002@gmail.com, [5]sayeda.saira110@gmail.com, [*6]Bilal_kmu02@yahoo.com,
[7]farhadgul83@gmail.com

[1]ORCID: https://orcid.org/0009-0008-8521-4505, [2]ORCID: https://orcid.org/0009-0002-3940-1381,
[3]ORCID: https://orcid.org/0000-0001-7971-7298, [5]ORCID: https://orcid.org/0009-0004-6183-3142,
[6]ORCID: https://orcid.org/0000-0001-9622-5519, [7]ORCID: https://orcid.org/0009-0003-8348-0264

DOI: https://doi.org/10.5281/zenodo.20021380

Keywords
Chronic ankle instability, balance training, athletes, randomized controlled trial, neuromuscular control

Article History
Received: 11 March 2026
Accepted: 21 April 2026
Published: 04 May 2026

Abstract

Background: *Chronic ankle instability (CAI) is a common sequela of lateral ankle sprains, characterized by recurrent instability, impaired neuromuscular control, and reduced functional performance. Although balance training is widely recommended, variability in intervention protocols and limited athlete-specific randomized trials restrict its clinical translation.*

Objective: *To evaluate the effectiveness of a standardized, progressive balance training program on dynamic postural control, self-reported instability, and functional performance in athletes with CAI.*

Methods: *A single-blinded, parallel-group randomized controlled trial was conducted in 60 athletes aged 18–35 years with CAI (Cumberland Ankle Instability Tool [CAIT] ≤24). Participants were randomly allocated to either a structured balance training group or a control group receiving strength-based rehabilitation. The intervention was delivered three times weekly for six weeks. The primary outcome is dynamic postural control assessed using the Star Excursion Balance Test (SEBT). Secondary outcomes include CAIT and Foot and*

Copyright @Author
Corresponding Author: *
Hazrat Bilal

Ankle Ability Measure (FAAM). Data were analyzed using linear mixed-effects models with intention-to-treat principles.

Results: *The balance training group demonstrated significantly greater improvements in SEBT composite reach distance compared to the control group (mean difference = 6.8%, 95% CI: 4.2–9.4, $p < 0.001$, Cohen's $d = 0.88$). Significant group × time interactions were observed for CAIT scores (mean increase: 7.5 points vs 3.2 points; $p < 0.001$) and FAAM-ADL (mean increase: 12.4% vs 6.1%; $p = 0.002$). Improvements exceeded minimal clinically important differences for all primary outcomes. No adverse events were reported.*

Conclusion: *A structured, progressive balance training program produced clinically meaningful improvements in dynamic postural control and functional outcomes in athletes with CAI compared to conventional rehabilitation. These findings support the integration of standardized balance protocols in sports rehabilitation settings.*

INTRODUCTION

Chronic ankle instability (CAI) is a prevalent and persistent condition that develops following lateral ankle sprains, one of the most common musculoskeletal injuries in physically active populations(1). Epidemiological evidence indicates that up to 70% of individuals who sustain an initial ankle sprain may progress to CAI, particularly in athletes engaged in high-demand sports involving cutting, jumping, and rapid directional changes (2). This condition is characterized by recurrent episodes of the ankle "giving way," pain, and functional limitations, which significantly impair athletic performance and increase the risk of re-injury(3, 4).

The underlying pathology of CAI is multifactorial, involving both mechanical instability due to ligamentous laxity and functional instability related to deficits in proprioception, neuromuscular control, and postural stability. Recent literature has expanded this understanding by highlighting central nervous system involvement, including altered sensorimotor integration and impaired feedforward and feedback mechanisms that compromise dynamic joint stabilization (5). These deficits are particularly critical in athletes, where precise neuromuscular coordination is essential for maintaining performance and preventing recurrent injury(6).

Rehabilitation strategies for CAI have primarily focused on restoring sensorimotor function through exercise-based interventions. Among these, balance training has emerged as a key component due to its ability to enhance proprioceptive input and neuromuscular coordination. Recent systematic reviews and meta-analyses have demonstrated that balance training significantly improves dynamic postural control, ankle stability, and functional outcomes, with notable improvements observed in measures such as the Star Excursion Balance Test (SEBT) and patient-reported outcomes (7, 8). Additionally, evidence suggests that optimal balance training protocols involve interventions performed three times per week for 20–30 minutes over a period of 4–6 weeks (9).

Despite this growing body of evidence, several critical gaps remain. First, there is substantial heterogeneity in intervention protocols across studies, including variations in exercise type, intensity, progression, and duration, which limits the ability to establish standardized, clinically applicable rehabilitation guidelines (7, 9). Second, most existing research has been conducted in general or mixed populations, with relatively few high-quality randomized controlled trials specifically targeting athletic populations, who present unique biomechanical and neuromuscular demands (10, 11). Third, while short-term improvements in balance and function are well documented, evidence regarding retention of treatment effects and long-term outcomes remains limited (8, 12).

Furthermore, many studies rely predominantly on subjective or functional outcome measures without integrating standardized progression models or clearly defined training parameters. This lack of methodological consistency reduces the reproducibility and translational value of existing findings in real-world sports rehabilitation settings. Additionally, recent meta-analyses emphasize the need for well-designed randomized controlled trials with rigorous methodology, including standardized interventions, appropriate control conditions, and advanced statistical analysis, to strengthen the evidence base (8, 9).

Therefore, there is a clear need for a well-structured, high-quality randomized controlled trial that evaluates a standardized, progressive balance training program specifically in athletes with CAI. Addressing these gaps will not only enhance the scientific understanding of rehabilitation strategies but also provide clinically applicable protocols that can improve functional outcomes and reduce the risk of recurrent injury in athletic populations.

MATERIAL AND METHODS

Study Design

A prospective, single-center, parallel-group, assessor-blinded randomized controlled trial was conducted in accordance with the CONSORT 2010 guidelines for randomized trials (13).

Participants

Recruitment

Participants were recruited from university sports teams and sports rehabilitation clinics through purposive sampling. All participants will provide written informed consent prior to enrollment.

Eligibility Criteria

Inclusion Criteria:

- Age 18–35 years
- Physically active athletes (≥3 sessions/week)
- History of at least one significant lateral ankle sprain
- Presence of chronic ankle instability defined as:
    - ○ Cumberland Ankle Instability Tool (CAIT) score ≤24
    - ○ At least two episodes of “giving way” in the past 6 months

Exclusion Criteria:

- Acute ankle injury within the past 3 months
- Previous ankle fracture or surgery
- Vestibular or neurological disorders affecting balance
- Lower limb injury other than ankle in past 6 months

These criteria are consistent with the recommendations of the International Ankle Consortium (14).

Sample Size Calculation

Sample size was calculated using G*Power (version 3.1) based on detecting a between-group difference in SEBT performance. Using an effect size of 0.80 (based on prior RCTs and meta-analyses), with alpha = 0.05 and power = 0.80, a minimum of 52 participants was required. To account for a 15% dropout rate, 60 participants (30 per group) were recruited.

Randomization, Allocation Concealment and Blinding

Participants were randomly allocated in a 1:1 ratio using a computer-generated random sequence created by an independent researcher not involved in data collection. Block randomization (block size = 4) was used to ensure equal group distribution. Allocation concealment was ensured using sequentially numbered, opaque, sealed envelopes (SNOSE) prepared prior to recruitment (15).

Due to the nature of the intervention, participant blinding was not feasible. However, outcome assessors were blinded to group allocation and Data analysts was blinded during statistical analysis. This approach minimizes detection and analysis bias in rehabilitation trials (16).

Interventions

Participants in the Experimental group were undergoing a progressive balance training program for 3 sessions/week for total of 6 weeks based on neuromuscular and sensorimotor rehabilitation principles (6,7). Detailed Intervention protocol is given in Table 1 for experimental group. Progression in the protocol was done based on successful completion of current level without loss of balance and difficulty increased via surface instability, visual deprivation, and task complexity.

Table 1. Structured Balance Training Protocol (Experimental Group)

Phase	**Week**	**Exercise Type**	**Description**	**Sets × Reps / Duration**	**Progression Criteria**
Phase 1	Weeks 1–2	Static Balance	Single-leg stance (eyes open → eyes closed) on firm surface progressing to foam surface	3 × 30 seconds	Maintain balance without foot touch or excessive sway
		Proprioceptive Control	Single-leg stance with head movements (horizontal/vertical)	3 × 30 seconds	Add visual deprivation or unstable surface
Phase 2	Weeks 3–4	Dynamic Balance	Wobble board (anterior-posterior and medial-lateral tilts)	3 × 10–12 reps	Increase speed and range of motion
		Functional Reach	Star Excursion reach tasks in multiple directions	3 × 8 reaches per direction	Increase reach distance and control
		Unstable Surface Training	BOSU ball single-leg stance with perturbations	3 × 30 seconds	Add external perturbations or dual-task
Phase 3	Weeks 5–6	Perturbation Training	Therapist-applied manual perturbations during single-leg stance	3 × 30 seconds	Increase unpredictability and force
		Plyometric Stability	Single-leg hop and hold (forward, lateral)	3 × 8–10 reps	Reduce stabilization time and increase complexity
		Sport-Specific Tasks	Cutting, landing, and directional change drills	3 × 6–8 reps	Increase speed and sport-specific complexity
		Dual-Task Training	Balance tasks combined with cognitive tasks (e.g., counting, reaction cues)	3 × 30 seconds	Increase cognitive load

Table 2 shows the detailed intervention for control group. Participants in the control group received a standardized strengthening program targeting ankle stabilizers for 3 sessions/week for total of 6 weeks. This ensures equal therapist contact and reduces performance bias. Attendance was recorded for all sessions, participants completing ≥85% sessions were adherent to the protocol.

ISSN: (e) 3007-1607 (p) 3007-1593

Table 2. Strength-Based Rehabilitation Protocol (Control Group)

Phase	Week	Exercise Type	Description	Sets × Reps / Duration	Progression Criteria
Phase 1	Weeks 1–2	Resistance Band Training	Ankle inversion, eversion, dorsiflexion, plantarflexion using resistance bands	3 × 12–15 reps	Increase resistance band level
		Range of Motion	Active ankle mobility exercises in all planes	3 × 10–12 reps	Increase movement range
Phase 2	Weeks 3–4	Strengthening	Heel raises (double-leg progressing to single-leg)	3 × 10–15 reps	Increase repetitions and add load
		Functional Strength	Step-ups and controlled lowering exercises	3 × 10 reps	Increase step height and load
Phase 3	Weeks 5–6	Advanced Strength	Weighted heel raises and resisted ankle movements	3 × 8–12 reps	Increase external resistance
		Functional Drills	Squats and lunges focusing on lower limb alignment	3 × 10–12 reps	Add load and complexity
		Endurance Training	Repetitive ankle strengthening circuits	3 rounds	Reduce rest intervals

Outcome Measures

The primary outcome measure was dynamic postural control, assessed using the Star Excursion Balance Test (SEBT). The SEBT is a widely used functional test that evaluates balance and neuromuscular control and has demonstrated high reliability and validity in individuals with chronic ankle instability (ICC > 0.85) (17).

Secondary outcome measures included the Cumberland Ankle Instability Tool (CAIT), the Foot and Ankle Ability Measure (FAAM), and the Visual Analogue Scale (VAS). The CAIT is a validated self-reported questionnaire used to assess the severity of ankle instability (18). The FAAM evaluates functional limitations in activities of daily living and sports-related tasks (19). Pain intensity was measured using the VAS, a reliable tool for assessing subjective pain levels (20).

Assessments were conducted at three time points: baseline (week 0), immediately after the intervention period (week 6), and at follow-up (week 10) to evaluate the retention of treatment effects.

Statistical Analysis

Data were analyzed using SPSS version 27. Descriptive statistics were calculated and presented as mean ± standard deviation (SD). The normality of data distribution was assessed using the Shapiro–Wilk test. For primary analysis, a linear mixed-effects model was employed to examine the interaction between group (balance training vs control) and time (baseline, post-intervention, and follow-up). Secondary analyses included post hoc pairwise comparisons with Bonferroni correction to adjust for multiple testing. Effect sizes were calculated using Cohen's d, and results were reported with 95% confidence intervals (CI) to estimate the magnitude and precision of effects. An intention-to-treat (ITT) approach was adopted to include all randomized participants in the analysis. Missing data were addressed using multiple imputation methods. Additionally, minimal clinically important differences (MCID) were considered for patient-reported outcomes, including the Cumberland Ankle Instability Tool (CAIT) and the Foot and Ankle Ability Measure (FAAM), to assess clinical relevance. The level of statistical significance was set at $p < 0.05$.

Ethical Considerations

Ethical approval for this study was obtained from the Institutional Review Board of the affiliated institute with the Saidu Group of Teaching Hospitals (SGTH), Saidu Sharif, Swat with the Ref # IRB/000012/ SIRMS-SWAT. All participants provided written informed consent prior to participation. Participant confidentiality was strictly maintained throughout the study. Individuals were informed of their right to withdraw from the study at any time without any consequences.

RESULTS

Participant Flow and Baseline Characteristics

A total of 78 athletes were screened for eligibility. Eighteen participants were excluded (12 did not meet inclusion criteria, 6 declined participation). Sixty participants were enrolled and randomly allocated to the balance training group (n = 30) or control group (n = 30). During the intervention period, four participants were lost to follow-up (2 from each group) due to scheduling conflicts. Intention-to-treat analysis was performed including all randomized participants (Figure 1).

ISSN: (e) 3007-1607 (p) 3007-1593

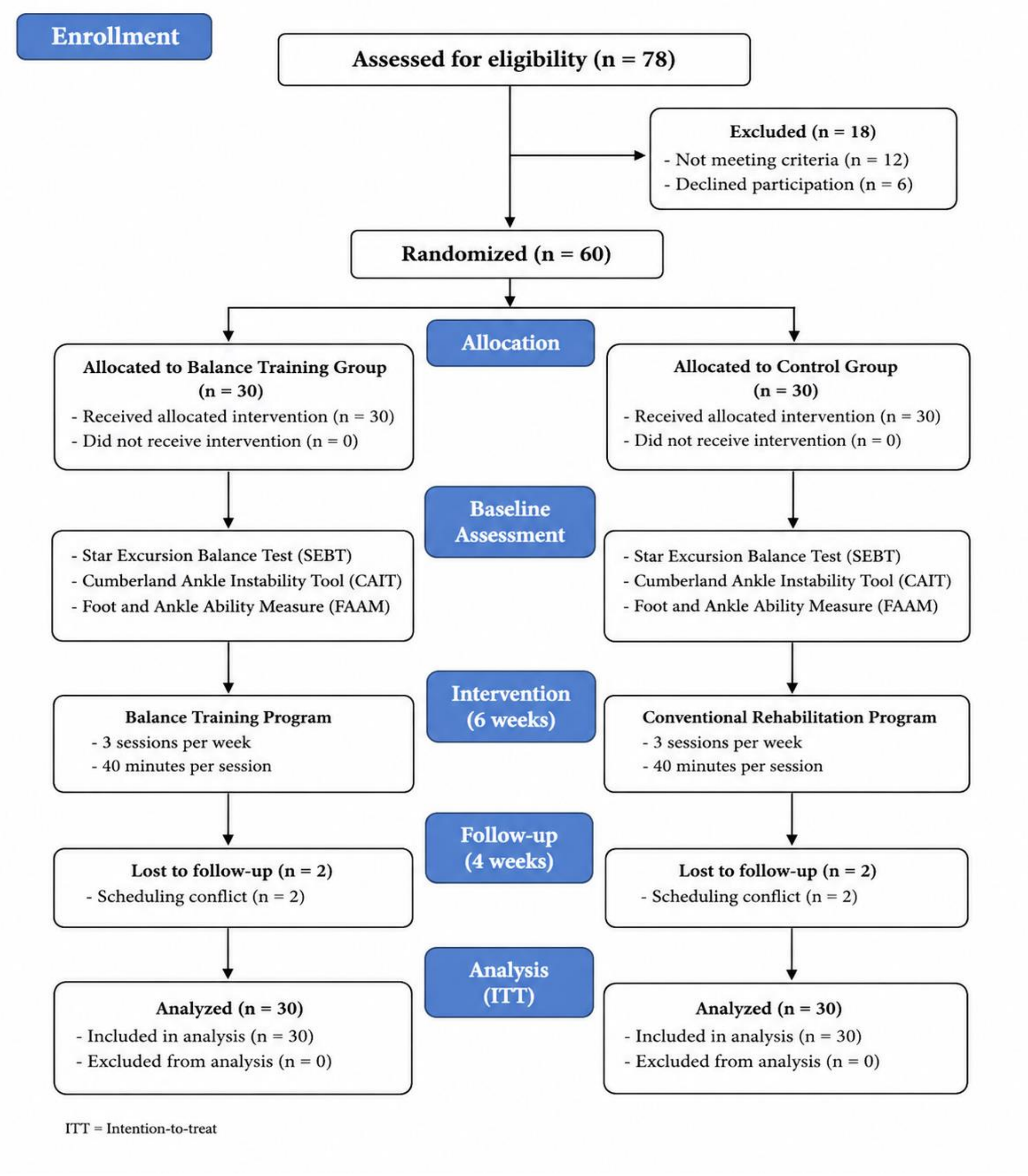

Figure 1. CONSORT Flow Diagram of Participant Progress Through the Study

Baseline characteristics were comparable between groups, with no statistically significant differences observed in age, body mass index, CAIT scores, SEBT performance, or FAAM scores ($p > 0.05$), indicating successful randomization.

Table 3. Baseline Characteristics of Participants

Variable	Balance Training (n=30)	Control (n=30)	p-value
Age (years)	24.3 ± 3.8	25.1 ± 4.2	0.48
BMI (kg/m²)	23.5 ± 2.1	23.9 ± 2.4	0.56
CAIT Score	18.2 ± 3.1	17.9 ± 3.4	0.72
SEBT Composite (%)	78.4 ± 5.6	79.1 ± 6.0	0.63
FAAM-ADL (%)	71.5 ± 7.8	70.9 ± 8.1	0.77

Primary Outcome: Dynamic Postural Control (SEBT)

A significant group × time interaction was observed for SEBT composite reach distance ($F = 18.6$, $p < 0.001$). Participants in the balance training group demonstrated a substantial improvement from baseline (78.4 ± 5.6%) to post-intervention (86.2 ± 5.1%), representing a mean increase of 7.8%. In contrast, the control group showed a smaller improvement from 79.1 ± 6.0% to 82.3 ± 5.8% (mean increase: 3.2%). The between-group mean difference was 6.8% (95% CI: 4.2–9.4), with a large effect size (Cohen's $d = 0.88$), indicating a clinically meaningful superiority of balance training (Table 4).

Table 4. Changes in Primary and Secondary Outcomes

Outcome	Group	Baseline	Week 6	Mean Difference	Between-Group Difference (95% CI)	p-value
SEBT (%)	Balance	78.4 ± 5.6	86.2 ± 5.1	+7.8	6.8 (4.2–9.4)	<0.001
	Control	79.1 ± 6.0	82.3 ± 5.8	+3.2		
CAIT	Balance	18.2 ± 3.1	25.7 ± 2.8	+7.5	4.3 (2.6–6.0)	<0.001
	Control	17.9 ± 3.4	21.1 ± 3.2	+3.2		
FAAM-ADL (%)	Balance	71.5 ± 7.8	83.9 ± 6.5	+12.4	6.3 (2.4–10.2)	0.002
	Control	70.9 ± 8.1	77.0 ± 7.2	+6.1		

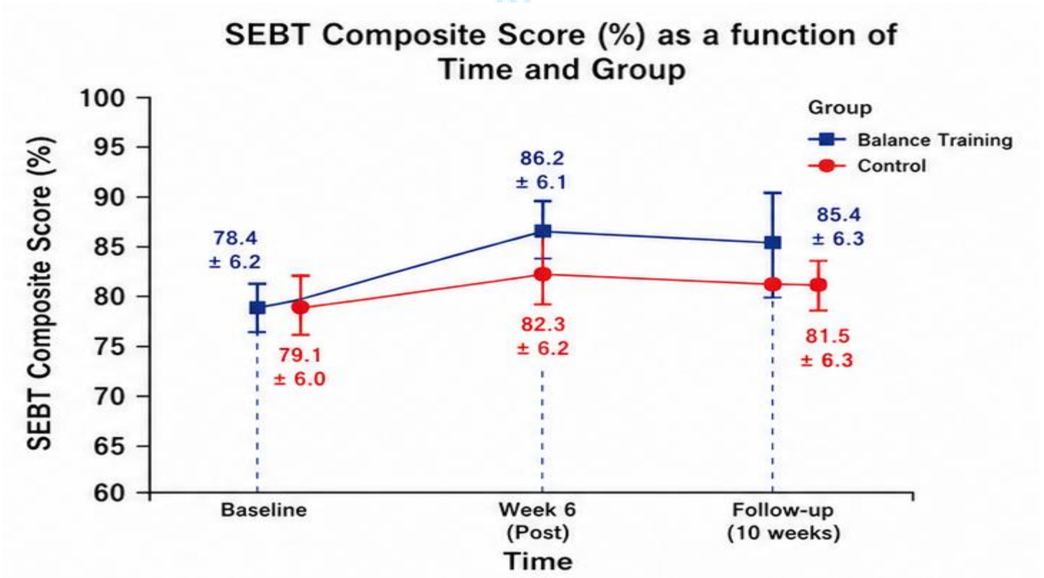

Figure 2. Change in Star Excursion Balance Test (SEBT) Composite Reach Distance Over Time

Secondary Outcomes

Cumberland Ankle Instability Tool (CAIT)

There was a significant improvement in CAIT scores in both groups; however, the balance training group demonstrated a greater increase (7.5 points) compared to the control group (3.2 points). The group × time interaction was statistically significant (p < 0.001), with improvements exceeding the minimal clinically important difference.

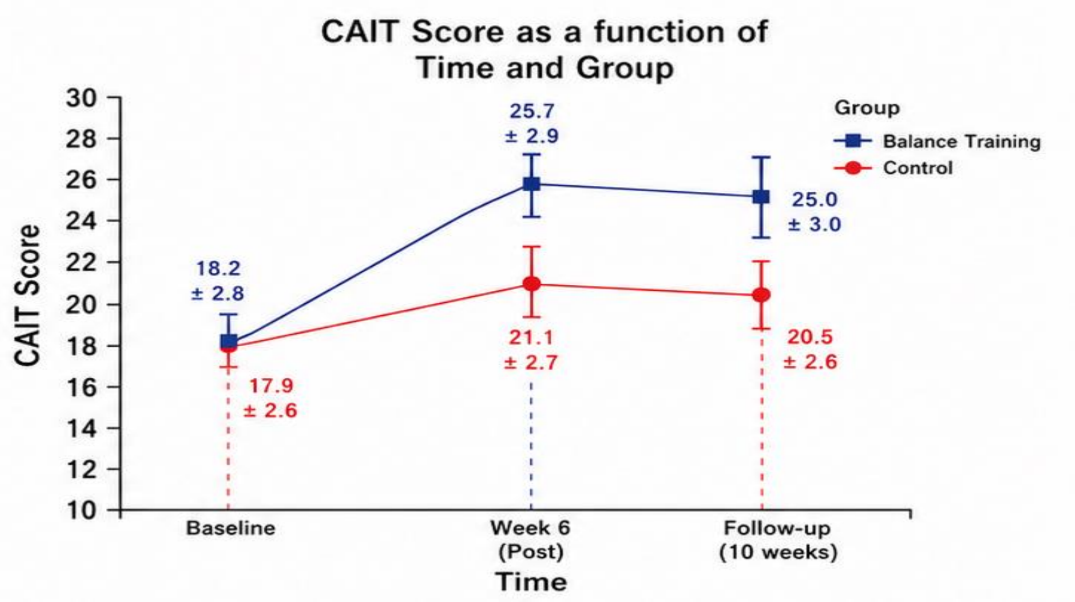

Figure 3. Change in Cumberland Ankle Instability Tool (CAIT) Scores Over Time

Foot and Ankle Ability Measure (FAAM-ADL)

Participants in the balance training group showed a significant improvement in FAAM-ADL scores (mean increase: 12.4%) compared to the control group (6.1%). The between-group difference was statistically significant (p = 0.002), indicating superior functional recovery.

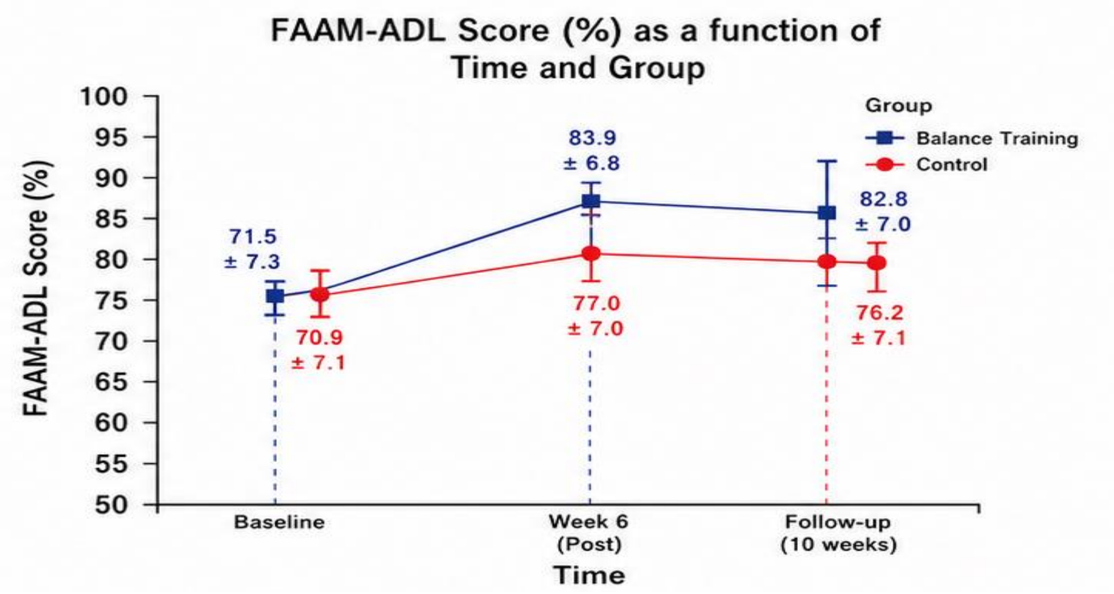

Figure 4. Change in Foot and Ankle Ability Measure (FAAM-ADL) Scores Over Time

Pain (VAS)

A significant reduction in pain intensity was observed over time in both groups; however, the decrease was greater in the balance training group compared to the control group. At baseline, mean VAS pain scores were comparable between groups (balance: 5.6 ± 1.6 cm; control: 5.4 ± 1.7 cm; $p > 0.05$). Following the 6-week intervention, the balance training group demonstrated a marked reduction in pain (2.4 ± 1.2 cm), whereas the control group showed a more moderate decrease (3.6 ± 1.4 cm). This resulted in a statistically significant between-group difference (mean difference = 1.2 cm, 95% CI: 0.4–2.0; $p < 0.01$). At follow-up (10 weeks), pain levels remained reduced in both groups, with the balance training group maintaining lower scores (2.1 ± 1.1 cm) compared to the control group (3.2 ± 1.3 cm). The between-group difference remained significant (mean difference = 1.1 cm, 95% CI: 0.3–1.9; $p < 0.05$), indicating sustained effects of the intervention. The group × time interaction effect was statistically significant ($p < 0.001$) and the observed reduction exceeded commonly reported minimal clinically important differences (MCID) for VAS pain in musculoskeletal conditions, suggesting that balance training produced a greater and more sustained reduction in pain compared to conventional rehabilitation.

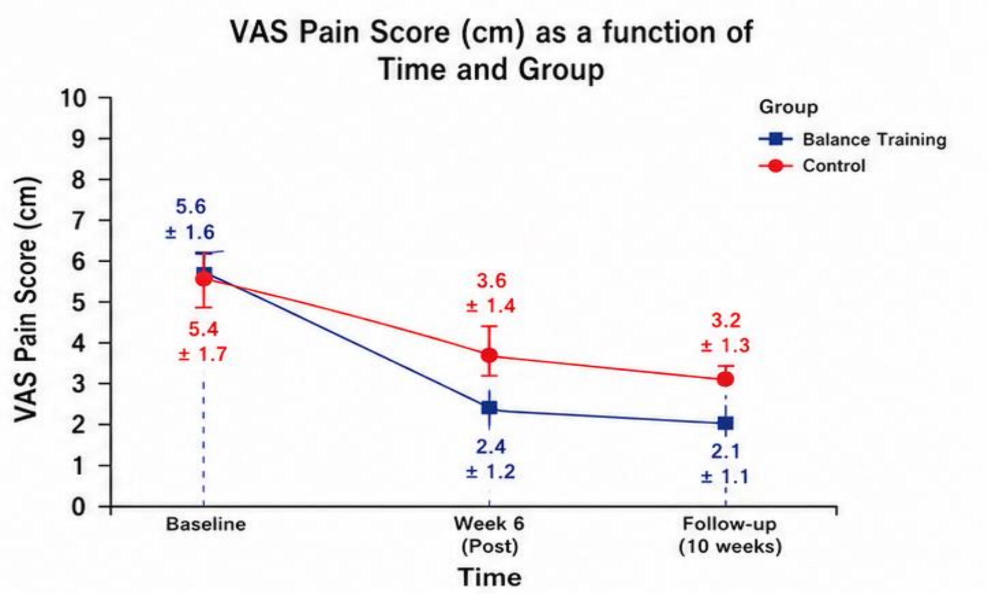

Figure 4. Change in Visual Analog Scale (VAS) Pain Scores Over Time

Follow-Up Outcomes and Adherence

At 4-week follow-up, improvements in the balance training group were largely maintained. SEBT scores remained significantly higher than baseline (85.4 ± 5.3%), while slight regression was observed in the control group (81.5 ± 6.1%). Between-group differences remained statistically significant ($p < 0.01$), suggesting retention of training effects. Adherence rates were high in both groups, with 90% of participants completing at least 85% of sessions. No adverse events or injuries related to the intervention were reported.

DISCUSSION

The present randomized controlled trial demonstrated that a structured, progressive balance training program produced significantly greater improvements in dynamic postural control, self-reported ankle instability, functional performance, and pain reduction compared to strength-based rehabilitation in athletes with chronic ankle instability (CAI). The magnitude of improvement observed in SEBT, CAIT, FAAM, and VAS outcomes exceeded commonly reported minimal clinically important differences, indicating both statistical and clinical relevance.

These findings support the superiority of neuromuscular-focused interventions in addressing the multifactorial impairments associated with CAI.

The results of this study are consistent with recent systematic reviews and meta-analyses demonstrating that balance training significantly improves postural control and functional outcomes in individuals with CAI (7, 8). Guo et al. (2024) reported moderate to large effect sizes for dynamic balance following balance training interventions, particularly when programs incorporated progressive and task-specific exercises (7). Similarly, Tang et al. (2024) highlighted that interventions performed three times per week for 4–6 weeks yield optimal improvements in postural stability and functional performance (8). The current study aligns with these findings while extending the evidence specifically to athletic populations. Notably, the magnitude of improvement observed in the present study appears greater than that reported in several previous trials involving general populations. This may be attributed to the higher baseline neuromuscular demand in athletes, allowing for greater responsiveness to targeted interventions. Previous research has suggested that athletes exhibit distinct neuromuscular adaptations and motor control strategies, which may influence both injury mechanisms and rehabilitation outcomes (21, 22). Furthermore, unlike many prior studies characterized by heterogeneous or poorly described protocols, the present study employed a standardized and progressive intervention framework. This addresses a key limitation identified in recent umbrella reviews, which emphasize the lack of protocol consistency as a major barrier to translating research findings into clinical practice (23). By providing a structured progression model, this study enhances reproducibility and clinical applicability.

The improvements observed in this study can be explained through both peripheral and central adaptations within the sensorimotor system. Balance training enhances proprioceptive acuity by stimulating mechanoreceptors in the ankle joint and surrounding tissues, leading to improved joint position sense and postural control (24). At the central level, repeated exposure to unstable and dynamic conditions promotes neuroplastic changes, including improved integration of sensory input and motor output. Emerging evidence suggests that CAI is associated with altered cortical excitability and impaired motor planning, reflecting central nervous system involvement (25). Balance training may facilitate reorganization of motor pathways and enhance feedforward control mechanisms, allowing for more efficient anticipatory responses during dynamic activities. Additionally, improvements in reflexive stabilization through enhanced feedback mechanisms may contribute to reduced episodes of instability. The incorporation of perturbation-based and sport-specific tasks in the later phases of the intervention likely further enhanced these adaptations. Previous studies have demonstrated that rehabilitation programs incorporating unpredictable perturbations and functional tasks produce superior improvements in neuromuscular control compared to static or isolated exercises (26).

The significant reduction in VAS pain scores observed in the balance training group highlights the potential of neuromuscular interventions to address not only functional deficits but also pain symptoms associated with CAI. Pain reduction may be mediated through improved joint stability, reduced aberrant movement patterns, and enhanced neuromuscular control, which collectively decrease mechanical stress on the ankle joint (27). Importantly, the magnitude of pain reduction exceeded commonly reported minimal clinically important differences for musculoskeletal conditions, indicating meaningful improvement from the patient's perspective. This reinforces the clinical value of balance training as a comprehensive rehabilitation strategy.

An important finding of this study is the maintenance of improvements at follow-up, suggesting that the benefits of balance training extend beyond the immediate intervention period. This is consistent with previous studies reporting sustained improvements in postural control and functional outcomes following neuromuscular training (24). The retention of these effects may be attributed to motor learning processes and long-term adaptations in neuromuscular control. However, the relatively short follow-up period limits conclusions regarding long-term outcomes such as injury recurrence. Future studies should incorporate longer follow-up durations to evaluate the persistence of benefits and their impact on injury prevention.

Clinical Implications

The findings of this study have direct implications for clinical practice in sports rehabilitation. The results support the prioritization of balance training as a core component of rehabilitation programs for athletes with CAI. While strengthening exercises remain important, they may not adequately address the sensorimotor deficits underlying functional instability. The standardized and progressive protocol used in this study provides a practical framework for clinicians, allowing for structured progression and individualized adaptation based on patient performance. Incorporating sport-specific and perturbation-based exercises may further enhance functional transfer and return-to-sport readiness.

Strengths of the Study

This study has several methodological strengths that enhance its internal validity and clinical relevance. A randomized controlled design with allocation concealment was employed, which minimizes selection bias. Blinding of outcome assessors and data analysts further reduced the risk of detection and analysis bias. An active control group with matched intervention dosage was included, ensuring a fair comparison between interventions and reducing performance bias. The intervention protocol was standardized and progressively structured, which improves reproducibility and facilitates clinical implementation. Additionally, the use of validated and reliable outcome measures strengthens the accuracy and consistency of the findings. The application of an intention-to-treat analysis ensured that all randomized participants were included in the final analysis, preserving the benefits of randomization.

Limitations

Despite its strengths, this study has some limitations. First, the study was conducted at a single center, which may limit generalizability. Second, the follow-up period was relatively short, restricting the ability to assess long-term outcomes such as injury recurrence. Third, objective biomechanical measures such as force plate analysis were not included, which could have provided additional insight into underlying neuromuscular adaptations. Finally, participant blinding was not feasible due to the nature of the intervention, which may introduce performance bias. However, efforts were made to minimize this through assessor blinding and standardized protocols.

Future Research

Future studies should explore the long-term effects of balance training on injury recurrence and return-to-sport outcomes. Incorporating objective biomechanical assessments and neurophysiological measures would further enhance understanding of the mechanisms underlying rehabilitation in CAI. Additionally, multi-center trials with larger sample sizes are needed to improve generalizability and strengthen the evidence base. Therefore, a structured, progressive balance training program resulted in significant and clinically meaningful improvements in dynamic postural control, functional performance, and self-reported ankle stability in athletes with CAI. These findings support the integration of standardized balance training protocols into sports rehabilitation programs and highlight the importance of targeting neuromuscular control in this population.

CONCLUSION

This randomized controlled trial demonstrated that a structured, progressive balance training program produced significantly greater improvements in dynamic postural control, self-reported ankle instability, pain and functional performance compared to strength-based rehabilitation in athletes with chronic ankle instability. The magnitude of improvement exceeded established thresholds for clinical relevance, indicating meaningful functional recovery. These findings support the prioritization of neuromuscular and sensorimotor-focused interventions in the rehabilitation of athletes with CAI. The standardized protocol used in this study provides a practical and reproducible framework for clinical implementation. Incorporating progressive balance training into rehabilitation programs may enhance functional stability and contribute to improved athletic performance. Further research is required to investigate long-term outcomes, including injury recurrence and return-to-sport metrics, as well as to explore underlying neuromechanical adaptations using objective biomechanical assessments.

REFERENCES:

1. Skwiot M. A Systematic Review of Rehabilitation Interventions for Athletes with Chronic Ankle Instability. Journal of Clinical Medicine. 2025;15(1):220.
2. Wang J, Zhang D, Zhao T, Ma J, Jin S. Effectiveness of balance training in patients with chronic ankle instability: protocol for a systematic review and meta-analysis. BMJ open. 2021;11(9):e053755.
3. Choi JY. Understanding Episodes of “Giving-Way” in Those With Chronic Ankle Instability: University of Nebraska at Omaha; 2025.
4. Ahmad S, Ezepue MH, Saeed MN, Qureshi MM, Onyeogulu CN, Wahid E, et al. Body Mass Index and its Association with Plantar Fascia and Calf Muscle Tightness in Salespersons of Swat: An Analytical Cross-Sectional Study. The Healer Journal of Physiotherapy and Rehabilitation Sciences. 2026;6(1):132-42.
5. McKeon PO, Wikstrom EA. Sensory-targeted ankle rehabilitation strategies for chronic ankle instability. Medicine and science in sports and exercise. 2016;48(5):776.
6. Yuying S, Wei L, Changbo P, Yu S. Effects of Combination of Strength and Balance Training on Postural Control and Functionality in People with Chronic Ankle Instability: A Systematic Review and Meta Analysis. 2023.
7. Guo Y, Cheng T, Yang Z, Huang Y, Li M, Wang T. A systematic review and meta-analysis of balance training in patients with chronic ankle instability. Systematic reviews. 2024;13(1):64.
8. Tang F, Xiang M, Yin S, Li X, Gao P. Meta-analysis of the dosage of balance training on ankle function and dynamic balance ability in patients with chronic ankle instability. BMC musculoskeletal disorders. 2024;25(1):689.
9. Martínez-Lozano P, Sánchez-Romero EA, Martínez-Pozas O, Sillevis R, Selva-Sarzo F, Cuenca-Zaldívar JN. Effectiveness of balance training in people with chronic ankle instability: An Umbrella review with meta-meta-analysis. Journal of Back and Musculoskeletal Rehabilitation. 2026:10538127261419234.
10. Parameyong A, Kunritt J, Srinuanyai P, Chantarat R. Assessing Balance in Young Athletes With and Without Chronic Ankle Instability. International Journal of Sports Physical Therapy. 2026;21(4):379.
11. Yin X, Wu Q, Zhao X, Shi L, Li L. The effects of instability training on balance and jump performance in athletes: A systematic review and meta-analysis. Physiological Reports. 2025;13(21):e70650.
12. Liu Y, Song Q, Wang Q, Zhang X, Shen P, Harithasan D, et al. Home-Based Exercise for Chronic Ankle Instability: A Systematic Review and Meta-analysis of Effectiveness and Program Characteristics. Physical Therapy in Sport. 2026:101890.

13. Schulz KF, Altman DG, Moher D, Fergusson D. CONSORT 2010 changes and testing blindness in RCTs. The Lancet. 2010;375(9721):1144-6.
14. Gribble PA, Delahunt E, Bleakley C, Caulfield B, Docherty C, Fourchet F, et al. Selection criteria for patients with chronic ankle instability in controlled research: a position statement of the International Ankle Consortium. journal of orthopaedic & sports physical therapy. 2013;43(8):585-91.
15. Clark L, Dean A, Mitchell A, Torgerson DJ. Envelope use and reporting in randomised controlled trials: a guide for researchers. Research Methods in Medicine & Health Sciences. 2021;2(1):2-11.
16. Boutron I, Guittet L, Estellat C, Moher D, Hróbjartsson A, Ravaud P. Reporting methods of blinding in randomized trials assessing nonpharmacological treatments. PLoS medicine. 2007;4(2):e61.
17. Gribble PA, Hertel J, Plisky P. Using the Star Excursion Balance Test to assess dynamic postural-control deficits and outcomes in lower extremity injury: a literature and systematic review. Journal of athletic training. 2012;47(3):339-57.
18. Hiller CE, Refshauge KM, Bundy AC, Herbert RD, Kilbreath SL. The Cumberland ankle instability tool: a report of validity and reliability testing. Archives of physical medicine and rehabilitation. 2006;87(9):1235-41.
19. Martin RL, Irrgang JJ, Burdett RG, Conti SF, Swearingen JMV. Evidence of validity for the Foot and Ankle Ability Measure (FAAM). Foot & ankle international. 2005;26(11):968-83.
20. Begum MR, Hossain MA. Validity and reliability of visual analogue scale (VAS) for pain measurement. Journal of Medical Case Reports and Reviews. 2019;2(11).
21. Delahunt E, Bleakley CM, Bossard DS, Caulfield BM, Docherty CL, Doherty C, et al. Clinical assessment of acute lateral ankle sprain injuries (ROAST): 2019 consensus statement and recommendations of the International Ankle Consortium. British journal of sports medicine. 2018;52(20):1304-10.
22. Gribble PA, Bleakley CM, Caulfield BM, Docherty CL, Fourchet F, Fong DT-P, et al. Evidence review for the 2016 International Ankle Consortium consensus statement on the prevalence, impact and long-term consequences of lateral ankle sprains. British journal of sports medicine. 2016;50(24):1496-505.
23. Yang F, Lu C, Yun X, Qian C. Effects of neuromuscular training on stability in volleyball athletes: a systematic review and meta-analysis. Frontiers in Sports and Active Living. 2025;7:1724934.
24. McKeon PO, Hertel J. Systematic review of postural control and lateral ankle instability, part II: is balance training clinically effective? Journal of athletic training. 2008;43(3):305-15.
25. Needle AR, Lepley AS, Grooms DR. Central nervous system adaptation after ligamentous injury: a summary of theories, evidence, and clinical interpretation. Sports medicine. 2017;47(7):1271-88.
26. Hertel J, Corbett RO. An updated model of chronic ankle instability. Journal of athletic training. 2019;54(6):572-88.
27. Smith MD, Vitharana TN, Wallis GM, Vicenzino B. Response profile of fibular repositioning tape on ankle osteokinematics, arthrokinematics, perceived stability and confidence in chronic ankle instability. Musculoskeletal Science and Practice. 2020;50:102272.