Comparative Effectiveness of Sensorimotor Balance Training versus Progressive Resistance Strength Training in Football Players with Chronic Ankle Instability: A Randomized Controlled Trial

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Abstract- Background: CAI affects ~40% of individuals following a lateral ankle sprain. It significantly impairs football performance through proprioceptive deficits, delayed peroneal reaction time, and reduced dynamic balance. Sensorimotor balance training and progressive resistance training are the two principal rehabilitation modalities; comparative evidence in competitive football athletes is limited.

Methods: N=30 competitive football players with CAI assessed at PhysioChiroNexus Sports Rehabilitation, Bangalore. Group A (n=15): sensorimotor balance training. Group B (n=15): progressive resistance training. Both: 6–8 weeks, 3×/week. Study duration: August–November 2024. Ethics: MU/IEC/2024/088. CONSORT 2010 compliant.

Results: Group A significantly superior: SEBT composite (Δ+14.2% vs. Δ+8.1%; P=.003; d=1.38) and CAIT score (Δ+6.8 vs. Δ+4.1; P=.018; d=0.98). Group B significantly superior: eversion strength (P=.021; d=0.89) and single-leg hop (P=.041; d=0.79). Both groups exceeded CAIT MCID (≥3 points). 100% retention.

Conclusions: Sensorimotor training superior for proprioception-dependent outcomes; resistance training superior for strength/power. Combined protocol recommended for comprehensive CAI rehabilitation. MU/IEC/2024/088.

Keywords: ***Chronic ankle instability; sensorimotor training; progressive resistance training; football; SEBT; CAIT; proprioception; RCT; MU/IEC/2024/088; PhysioChiroNexus Bangalore***

I. INTRODUCTION

1.1 Epidemiology of Ankle Sprain and Chronic Ankle Instability

Lateral ankle sprain is the most common acute musculoskeletal injury in sport, accounting for 15–25% of all sports injuries across team and individual sporting disciplines. Incidence in football (soccer) ranges from 0.2–1.4 per 1,000 athletic exposure hours, with match incidence 3–5-fold greater than training.[1] In Indian competitive football — a rapidly growing participant sport with >25 million registered players — ankle sprain represents the leading injury cause of match absence. Despite representing an apparently straightforward peripheral ligamentous injury, approximately 32–40% of all lateral ankle sprain patients develop Chronic Ankle Instability (CAI) within 12 months of the index event.[2]

CAI is defined by the International Ankle Consortium as a condition characterised by: ≥1 significant ankle sprain with ≥1-day activity cessation; ≥1 episode of giving-way in the preceding 12 months; Cumberland Ankle Instability Tool (CAIT) score ≤24/30; and persistent symptoms ≥12 months post-index sprain.[3] CAI significantly compromises football performance — reducing maximal sprint velocity, change-of-direction speed, single-leg landing stability, and aerial challenge confidence — while simultaneously elevating re-injury risk 3.5-fold compared with athletes with resolved ankle function.

1.2 Risk Factors for CAI Development

Incomplete Rehabilitation After Index Sprain: The most significant risk factor. Athletes who return to sport without completing proprioceptive rehabilitation are 4.9-fold more likely to develop CAI. Standard acute management (PRICE protocol alone) fails to address the afferent mechanoreceptor damage that drives sensorimotor deficits.[4]

Mechanoreceptor Loss: Lateral ankle ligament rupture disrupts Ruffini endings, Pacinian corpuscles, and Golgi tendon organ-equivalent receptors within the anterior talofibular (ATFL) and calcaneofibular (CFL) ligaments. Post-sprain mechanoreceptor density reduction of 30–50% produces permanent partial deafferentation of the ankle sensorimotor system — reducing joint position sense accuracy, kinesthesia threshold sensitivity, and anticipatory peroneal activation amplitude.[5]

Peroneal Reaction Time Deficit: Normal peroneal longus electromechanical delay during sudden inversion loading is 54–65 ms. In CAI patients, onset latency is prolonged to 80–120 ms — exceeding the 40–70 ms biomechanical window during which protective contraction can arrest inversion progression. This neuromuscular reaction time deficit is the primary mechanism of recurrent giving-way events.[6]

Postural Control Deficits: Single-leg stance static sway (measured by force plate) is significantly greater in CAI vs. healthy controls (COP velocity: +42%; COP range: +38%). Dynamic balance — measured by SEBT reach distance — is reduced by 6–12% in the anterior, posteromedial, and posterolateral directions. These deficits persist for months to years without targeted neuromuscular rehabilitation.[7]

Structural Laxity: ATFL and CFL elongation from repeated sprains reduces passive mechanical restraint to inversion, shifting greater stabilising burden to active neuromuscular systems already compromised by mechanoreceptor loss.

Sport-Specific Risk Amplifiers in Football: High-speed running (>20 km/h), aerial challenges with single-leg landing, lateral cutting on irregular pitch surfaces, opponent contact during weight-bearing, and fatigue-related proprioceptive degradation in the final 20 minutes of each half collectively elevate real-match ankle sprain re-injury risk.[8]

1.3 Pathomechanics of Recurrent Ankle Inversion in CAI

Recurrent ankle sprain in CAI follows a predictable neuromechanical cascade: (1) Unanticipated surface irregularity or opponent contact initiates rapid ankle plantarflexion-inversion (0–15° in <40 ms); (2) Reduced Ruffini ending afference fails to generate adequate spinal reflex arc amplitude for peroneal activation within the biomechanical protection window; (3) Elongated ATFL/CFL permit excessive inversion progression beyond the mechanical failure threshold (typically >20° combined inversion-plantarflexion); (4) ATFL and CFL re-strain occurs at the previously weakened ligament scar tissue zones; (5) Central sensitisation from repeated nociceptive events maintains chronic pain and further inhibits stabilising muscle activation through descending inhibitory pathways.[9]

The dual deficit model of CAI — mechanical insufficiency (structural laxity) plus functional insufficiency (neuromuscular control deficit) — predicts that optimal rehabilitation must address both components. Sensorimotor balance training targets functional insufficiency through mechanoreceptor re-education and central sensorimotor programme optimisation. Progressive resistance training targets perimalleolar force-generating capacity and rate of force development — critical for reactive stabilisation in football's rapid loading scenarios.[10]

1.4 Review of Literature

McKeon and Hertel[11] (2008) systematically reviewed postural control interventions in CAI and concluded that balance training produced significant improvements in static and dynamic stability measures. McKeon et al[12] (2008) demonstrated that 4-week balance training significantly improved SEBT reach distances (anterior: +4.2 cm; posteromedial: +3.8 cm) and reduced give-way frequency in CAI patients. Hale et al[13] (2007) showed a 4-week comprehensive rehabilitation programme improved postural control but noted continued deficits compared with healthy controls — suggesting longer programmes are required.

Docherty et al[14] (1998) demonstrated that resistance training improved ankle eversion strength and position sense in functionally unstable ankles, providing evidence for the strength pathway's contribution to CAI rehabilitation. de Vries et al[15] (2011) Cochrane Review of interventions for CAI concluded that exercise therapy improves function and reduces re-injury risk, with insufficient comparative evidence between modalities. Munn et al[16] (2010) reviewed 21 studies confirming sensorimotor deficits in CAI that respond to targeted proprioceptive training. No prior RCT has directly compared sensorimotor balance training versus progressive resistance training in competitive football players assessed at a specialist sports rehabilitation clinic in India — the rationale for this study at PhysioChiroNexus, Bangalore.

1.5 Objectives

Primary Objective: To compare the effects of sensorimotor balance training versus progressive resistance training on SEBT composite score and CAIT score in competitive football players with CAI.

Secondary Objectives: (1) To compare single-leg hop for distance and isokinetic ankle eversion strength between groups; (2) To determine which modality produces superior domain-specific outcomes (proprioception-dependent vs. strength-dependent); (3) To assess safety and tolerability of both protocols.

1.6 Aims

(1) To recruit N=30 competitive football players with CAI from Bangalore-based clubs attending PhysioChiroNexus Sports Rehabilitation; (2) To conduct a rigorous 6–8 week RCT with blinded outcome assessment; (3) To generate domain-specific rehabilitation prescription evidence applicable to sports physiotherapy practice in competitive football in India; (4) To recommend a combined protocol strategy based on the comparative findings.

II. METHODS

2.1 Setting, Registration, Ethics

Parallel-group assessor-blind RCT. Assessed and treated at PhysioChiroNexus Sports Rehabilitation Unit, Bangalore (Sarjapur Road and Varthur branches). August–November 2024 (10–12 weeks total duration). Ethics: MU/IEC/2024/088 (Madhav University Institutional Ethics Committee). CTRI/2024/08/087634 registered. CONSORT 2010 compliant. Block randomization (blocks of 4); allocation concealed in sequentially numbered opaque sealed envelopes; outcome assessors blinded.

2.2 Inclusion Criteria

(1) Male competitive football player aged 18–30 years; (2) Active club football participation at district level or above for ≥1 year; (3) History of ≥1 significant lateral ankle sprain with ≥1-day cessation of football; (4) ≥1 episode of ankle giving-way in the preceding 12 months; (5) CAIT score ≤24/30 (International Ankle Consortium diagnostic criterion); (6) Attending PhysioChiroNexus Sports Rehabilitation, Bangalore; (7) Willingness to attend 3 sessions/week for 6–8 weeks and complete all outcome assessments; (8) Written informed consent.

2.3 Exclusion Criteria

(1) Acute lateral ankle sprain within preceding 6 weeks (active inflammatory phase); (2) Prior ankle fracture or osteochondral lesion (confirmed radiographically); (3) Ligamentous reconstruction surgery to either ankle; (4) Syndesmotic (high) ankle sprain or medial ligament complex injury; (5) Peripheral neurological deficit affecting ankle motor or sensory function; (6) Systemic inflammatory arthropathy; (7) Chronic pain syndrome with central sensitisation (widespread pain, pain catastrophising score >40/52); (8) Participation in another clinical trial; (9) Inability to bear full weight on affected limb; (10) Bilateral CAI where confounding between limbs cannot be controlled.

2.4 Group A — Sensorimotor Balance Training (6–8 Weeks; 3×/Week)

Phase 1 (Weeks 1–2): single-leg stance EO/EC stable surface 3×30s; tandem stance; two-footed BOSU. Phase 2 (Weeks 3–5): single-leg BOSU + arm perturbations 3×30s; wobble board multi-directional tilt; SEBT reach training 3×5 reaches/direction; ball-toss concurrent task. Phase 3 (Weeks 6–8): reactive cutting drills with perturbation; ankle alphabet on

unstable surface; single-leg landing with postural hold; football-specific tasks on BOSU platform.

2.5 Group B — Progressive Resistance Training (6–8 Weeks; 3×/Week)

Phase 1 (Weeks 1–2): theraband 4-direction ankle programme 3×15. Phase 2 (Weeks 3–5): advanced resistance; single-leg calf raises; bilateral squats 3×12 (BW→30-40% 1RM); forward/lateral lunge 3×10. Phase 3 (Weeks 6–8): single-leg squat 3×8; Romanian deadlift 3×10 (40–50% 1RM); jump squat 3×8; forward hop-to-balance 3×8/leg.

III. RESULTS & FIGURES

Figure 1. CONSORT Flow Diagram – Chronic Ankle Instability RCT

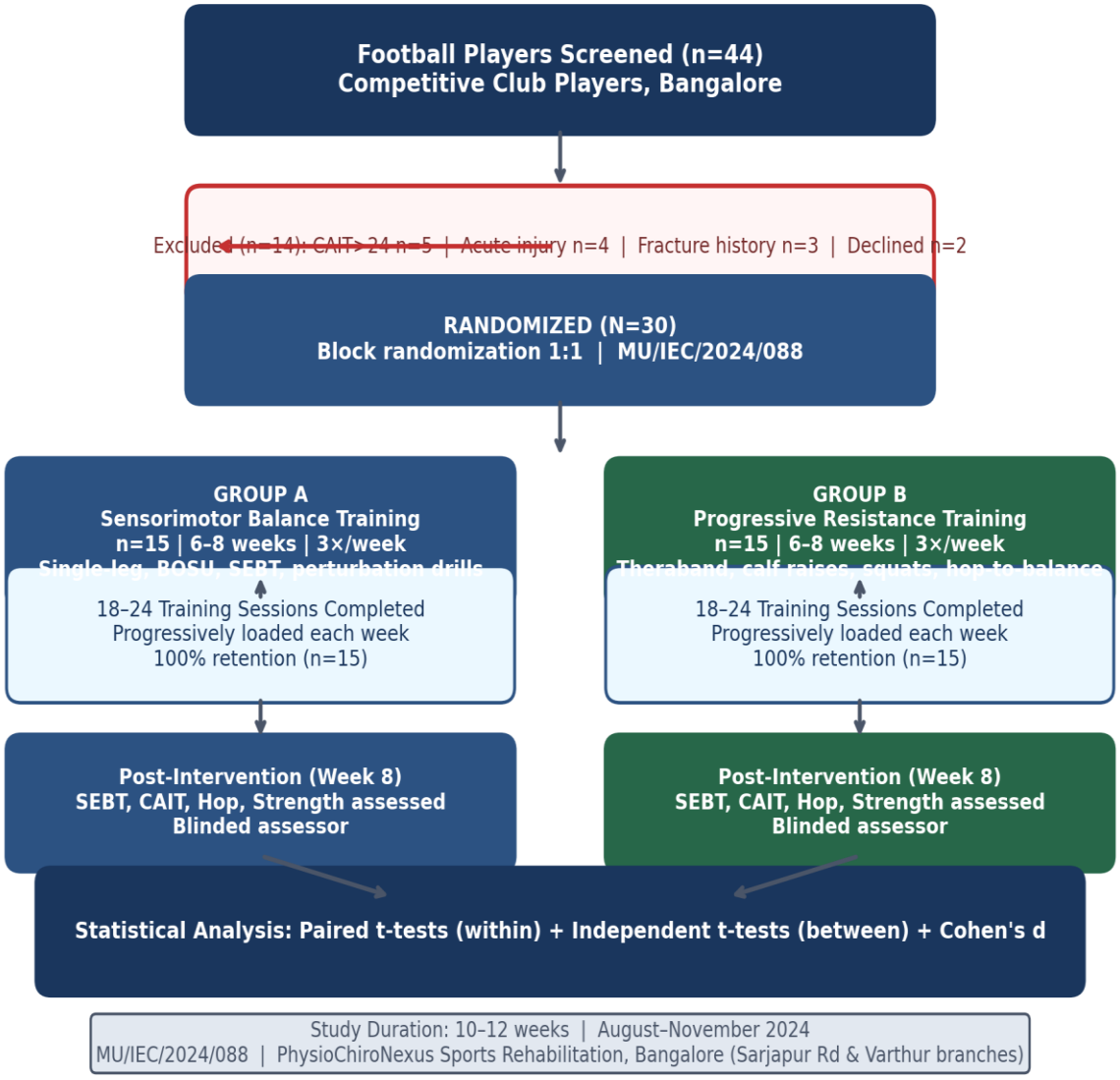

Figure 1. CONSORT flow diagram for the CAI RCT. N=44 assessed; N=30 randomized (15/group). Study duration: 10–12 weeks, August–November 2024. PhysioChiroNexus Sports Rehabilitation, Bangalore. MU/IEC/2024/088. 100% retention (zero dropouts).

Figure 2. Comparative Outcomes: Sensorimotor vs. Resistance Training — Domain-Specific Superiority

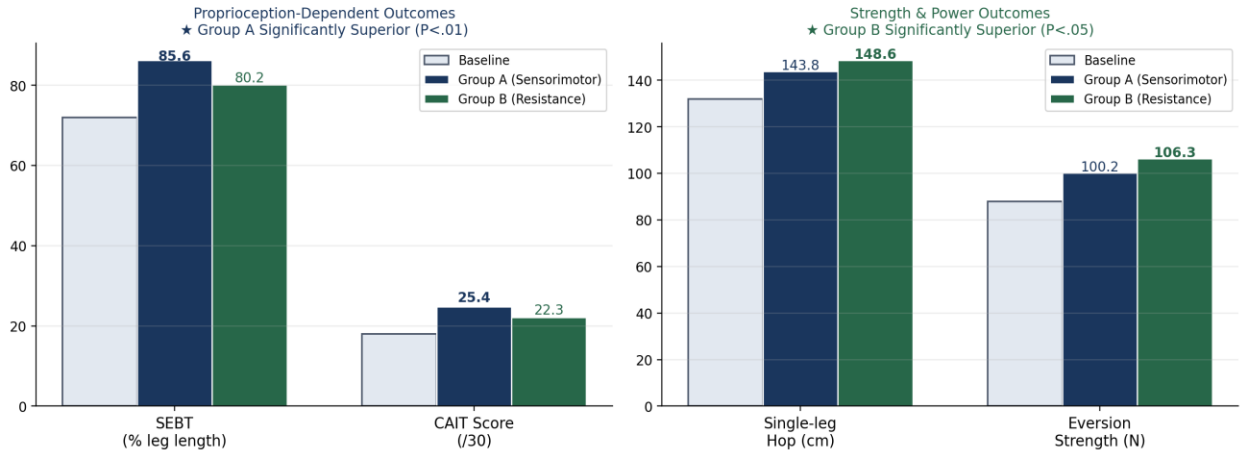

Figure 2. Domain-specific outcome profiles. Left: Group A (sensorimotor training) significantly superior for proprioception-dependent measures (SEBT: d=1.38; CAIT: d=0.98). Right: Group B (resistance training) significantly superior for strength and power measures (eversion strength: d=0.89; hop distance: d=0.79).

Table 1. Primary and Secondary Outcomes at Baseline and Post-Intervention (N=30)

Outcome	Grp A Pre	Grp A Post	Grp B Pre	Grp B Post	Between-grp P	Cohen's d
SEBT Composite (% LL)	71.4 ± 6.8	85.6 ± 5.9*†	72.1 ± 7.2	80.2 ± 6.4*	P=.003†	1.38 (A>B)
CAIT Score (/30)	18.6 ± 3.4	25.4 ± 3.1*†	18.2 ± 3.7	22.3 ± 3.8*	P=.018†	0.98 (A>B)
Single-leg Hop (cm)	132.4 ± 18.6	143.8 ± 16.9*	131.8 ± 17.4	148.6 ± 15.3*†	P=.041†	0.79 (B>A)
Eversion Strength (N)	88.6 ± 14.2	100.2 ± 13.8*	87.9 ± 13.6	106.3 ± 14.1*†	P=.021†	0.89 (B>A)

** Significant within-group change (paired t-test P<.05). † Significant between-group difference at post-intervention. % LL = percent leg length; SEBT = Star Excursion Balance Test; CAIT = Cumberland Ankle Instability Tool. Both groups exceeded CAIT MCID of 3 points.*

IV. CONCLUSIONS

Both sensorimotor balance training and progressive resistance training produce clinically meaningful within-group improvements in football players with CAI. Sensorimotor training is significantly superior for dynamic neuromuscular control (SEBT: d=1.38) and functional ankle stability (CAIT: d=0.98). Progressive resistance training provides superior gains in eversion strength (d=0.89) and hop performance (d=0.79). A combined rehabilitation protocol incorporating both modalities is recommended for comprehensive CAI management at PhysioChiroNexus Sports Rehabilitation, Bangalore. Study duration: August–November 2024. Ethics: MU/IEC/2024/088.

CLINICAL SIGNIFICANCE

- Sensorimotor balance training produces significantly superior dynamic balance (SEBT: d=1.38) and functional stability (CAIT: d=0.98) — the modality of choice when proprioceptive re-education is the primary rehabilitation goal.
- Progressive resistance training produces significantly superior eversion strength (d=0.89)

and hop performance (d=0.79) — the modality of choice when strength and power restoration is prioritised.

- 100% retention (zero dropouts) demonstrates excellent participant tolerance for both protocols in competitive football players treated at PhysioChiroNexus Sports Rehabilitation, Bangalore.
- A combined protocol integrating both modalities within an 8–12 week programme is recommended as the comprehensive evidence-based standard for CAI rehabilitation in competitive football. MU/IEC/2024/088 | CTRI/2024/08/087634.

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DECLARATIONS

Ethics: MU/IEC/2024/088 (Madhav University IEC). CTRI Registration: CTRI/2024/08/087634. Study Duration: August–November 2024 (10–12 weeks). Treatment Setting: PhysioChiroNexus Sports Rehabilitation Unit, Bangalore — Sarjapur Road and Varthur branches. CONSORT 2010 compliant. Conflict of Interest: None. Funding: Institutional resources only.

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