Effectiveness of Intrinsic Foot Muscle Strengthening versus Gluteal Muscle Strengthening, Each Combined with Balance Training, in Adults with Chronic Ankle Instability: A Randomized Comparative Study

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Abstract

Background and objectives: Chronic ankle instability (CAI) is a common sequela of recurrent lateral ankle sprains, producing impaired balance, reduced functional ability, and persistent pain. Rehabilitation traditionally targets either distal (foot) or proximal (hip) musculature. This study compared the effectiveness of intrinsic foot muscle strengthening combined with balance training against gluteal muscle strengthening combined with balance training in improving functional outcomes in adults with CAI.
Methods: Forty participants with CAI (CAIT ≤ 24) were randomly allocated in a 1:1 ratio to Group A (n = 20; intrinsic foot muscle strengthening + balance training) or Group B (n = 20; gluteal muscle strengthening + balance training). The intervention ran for 8 weeks, three supervised 45-minute sessions per week (24 sessions). Assessment was performed by a blinded assessor pre- and post-intervention. Analysis used paired and independent t-tests and repeated-measures ANOVA, with significance set at $p < 0.05$.
Outcome measures: Primary outcomes were the Cumberland Ankle Instability Tool (CAIT) and Star Excursion Balance Test (SEBT). Secondary outcomes were the Foot and Ankle Ability Measure (FAAM), Manual Muscle Testing (MMT), and the Visual Analogue Scale (VAS) for pain.
Results: Both groups improved significantly across all outcomes after intervention ($p < 0.001$). Group B showed significantly greater gains than Group A in functional stability, neuromuscular efficiency, and pain reduction (all between-group $p < 0.001$), with very large to extremely large effect sizes (Cohen's d 2.90–5.11). A significant time-by-group interaction confirmed a steeper recovery trend in Group B.
Conclusion: Both intrinsic foot muscle strengthening and gluteal muscle strengthening combined with balance training are effective for managing CAI; however, gluteal strengthening combined with balance training produces superior functional and pain outcomes, supporting a proximal-to-distal, kinetic-chain rehabilitation approach.

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Keywords: Chronic ankle instability, Intrinsic foot muscles, Gluteal strengthening, Balance training, CAIT, SEBT, Rehabilitation

1. Introduction

Lateral ankle sprain is among the most frequent musculoskeletal injuries in active populations, and a substantial proportion of those affected progress to chronic ankle instability (CAI). CAI is characterised by recurrent episodes of the ankle “giving way,” residual mechanical laxity, and sensorimotor deficits that together impair balance, reduce functional performance, and lower quality of life. According to the International Ankle Consortium, repeated lateral sprains commonly produce persistent functional limitation and diminished postural control.

Rehabilitation for CAI has historically focused on the ankle joint itself, emphasising local strengthening and proprioceptive retraining. The intrinsic foot muscles contribute to the "foot core" system, supporting the medial longitudinal arch and providing fine dynamic control during weight-bearing. Strengthening these muscles improves load distribution and distal stability. More recently, a proximal perspective has gained ground: weakness of the hip and gluteal musculature alters lower-limb alignment and neuromuscular control and has been associated with an increased risk of ankle instability. This has motivated a kinetic-chain approach in which proximal stability is treated alongside distal impairments.

Balance training is a common denominator across both strategies, improving postural control by challenging proprioceptive pathways and enhancing feedforward and feedback control. Despite mechanistic support for both distal and proximal strengthening, direct head-to-head comparison of the two approaches—each paired with an identical balance-training protocol—remains limited. The present study therefore compared intrinsic foot muscle strengthening with balance training against gluteal muscle strengthening with balance training, hypothesising that proximal strengthening would yield superior functional stability, balance, and pain outcomes in adults with CAI.

2. Materials and Methods

2.1. Study design

This was a prospective, single-blind, parallel-group randomised controlled comparative study. Participants were allocated 1:1 to an intrinsic foot muscle strengthening group or a gluteal muscle strengthening group, each combined with a common balance-training protocol. The outcome assessor was blinded to group allocation; blinding of participants and treating therapists was not feasible given the nature of the interventions.

2.2. Participants and setting

Forty adults with CAI were recruited by purposive sampling from the outpatient musculoskeletal physiotherapy department of a specialised foot-and-ankle rehabilitation centre. Following screening and written informed consent, participants were randomly allocated using a computer-generated sequence prepared by an independent researcher, with allocation concealment via sealed, opaque, sequentially numbered envelopes. Ethical approval was obtained from the Institutional Ethics Committee of Jagannath University, Jaipur.

2.3. Eligibility criteria

Inclusion: age 18–40 years; history of ankle sprain at least one year prior; VAS pain > 5; at least two episodes of "giving way"; and a diagnosis of CAI (CAIT ≤ 24).

Exclusion: recent acute ankle injury (≤ 3 months); lower-limb fracture or surgery; grade III ligament tear or complete rupture; generalised laxity or hypermobility; significant visual/auditory impairment; uncontrolled hypertension or cardiac disease; fixed lower-limb joint contractures; neurological disorders affecting balance; vestibular disorders; and systemic or inflammatory musculoskeletal conditions.

2.4. Outcome measures

Primary outcomes were the Cumberland Ankle Instability Tool (CAIT) and the Star Excursion Balance Test (SEBT). Secondary outcomes were the Foot and Ankle Ability Measure (FAAM), Manual Muscle Testing (MMT), and the Visual Analogue Scale (VAS) for pain. All measures were recorded at baseline and within one week of completing the intervention.

2.5. Interventions

Group A (intrinsic foot muscle strengthening): short-foot exercise, towel-curl exercise, and elastic-band great-toe strengthening.

Group B (gluteal muscle strengthening): clamshells, side-lying hip abduction, and standing hip abduction.

Common balance-training protocol: single-leg stance training and BOSU-ball training. All exercises began at 2 sets of 10 repetitions in weeks 1–4 and progressed to 4 sets of 10 repetitions in weeks 5–8, with prescribed holds. The programme ran for 8 weeks at three supervised 45-minute sessions per week (24 sessions).

2.6. Statistical analysis

Within-group change was analysed using paired t-tests and between-group differences using independent t-tests on change scores; repeated-measures ANOVA evaluated time-by-group interaction. Effect sizes were quantified using Cohen's d (small 0.2, medium 0.5, large 0.8), and 95% confidence intervals (CI) were reported. MMT, being ordinal, was interpreted non-parametrically. Significance was set at $p < 0.05$.

3. Results

All 40 participants completed the study with no dropouts. Baseline comparisons confirmed group homogeneity for age, injury duration, and all outcome measures (Tables 1 and 2).

3.1. Baseline characteristics

Table 1: Baseline demographic characteristics of the two groups.

Variable	Group A (n = 20)	Group B (n = 20)	t value	p value
Age (years), mean ± SD	27.3 ± 5.03	28.2 ± 4.31	0.61	0.54
Pain / injury duration (days)	268 ± 54.9	270 ± 54.7	0.12	0.90
Female : Male	14 : 6	8 : 12	–	–

The mean age of Group A was 27.3 ± 5.03 years and of Group B 28.2 ± 4.31 years, with no significant difference (t = 0.61, p = 0.54). Injury duration was likewise comparable (p = 0.90). Group A was predominantly female and Group B predominantly male; because the study focused on functional gains, and baseline outcome homogeneity was confirmed, this imbalance was treated as a minor, non-primary confounder.

Table 2: Baseline comparison of outcome measures between groups.

Outcome	Group A (Mean ± SD)	Group B (Mean ± SD)	t value	p value
CAIT	14.9 ± 1.6	15.8 ± 1.5	−1.84	0.07
SEBT	53.1 ± 2.8	54.6 ± 2.6	−1.76	0.09
FAAM	59.3 ± 3.1	61.2 ± 3.0	−1.97	0.06
MMT	3.0 ± 0.0	3.0 ± 0.0	0.00	1.00
VAS	7.0 ± 0.7	7.1 ± 0.8	−0.42	0.67

No between-group difference reached significance at baseline (all p > 0.05), confirming successful randomisation.

3.2. Within-group changes

Table 3: Pre- and post-treatment comparison within Group A (IFM + balance training).

Outcome	Pre (Mean ± SD)	Post (Mean ± SD)	Mean diff.	95% CI	p value
CAIT	14.9 ± 1.6	21.4 ± 1.3	6.5	5.9–7.1	<0.001
SEBT	53.1 ± 2.8	64.2 ± 2.6	11.1	10.2–12.0	<0.001
FAAM	59.3 ± 3.1	73.0 ± 2.9	13.7	12.6–14.8	<0.001
MMT	3.0 ± 0.0	4.0 ± 0.0	1.0	–	<0.001*
VAS	7.0 ± 0.7	3.6 ± 0.6	3.4	2.9–3.9	<0.001

Table 4: Pre- and post-treatment comparison within Group B (gluteal + balance training).

Outcome	Pre (Mean ± SD)	Post (Mean ± SD)	Mean diff.	95% CI	p value
CAIT	15.8 ± 1.5	28.3 ± 1.4	12.5	11.8–13.2	<0.001
SEBT	54.6 ± 2.6	73.4 ± 2.5	18.8	17.6–20.0	<0.001
FAAM	61.2 ± 3.0	87.1 ± 3.2	25.9	24.4–27.4	<0.001
MMT	3.0 ± 0.0	5.0 ± 0.0	2.0	–	<0.001*
VAS	7.1 ± 0.8	2.0 ± 0.5	5.1	4.5–5.7	<0.001

Both groups improved significantly on every measure (all p < 0.001), with 95% CIs for mean differences not crossing zero. *MMT was ordinal and interpreted non-parametrically.

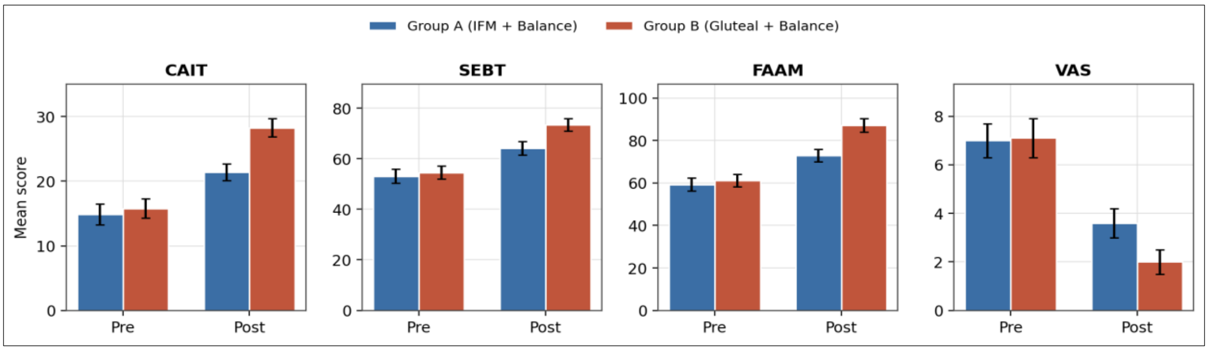

Fig 1: Pre- and post-intervention mean scores by group for CAIT, SEBT, FAAM, and VAS (error bars = SD).

3.3. Between-group comparison

Table 5: Post-treatment comparison of outcomes between groups.

Outcome	Group A	Group B	Mean diff.	95% CI	t value	p value
CAIT	21.4 ± 1.3	28.3 ± 1.4	6.9	5.9–7.9	−16.16	<0.001
SEBT	64.2 ± 2.6	73.4 ± 2.5	9.2	7.8–10.6	−11.42	<0.001
FAAM	73.0 ± 2.9	87.1 ± 3.2	14.1	12.5–15.7	−14.60	<0.001
MMT	4.0 ± 0.0	5.0 ± 0.0	1.0	–	–	<0.001*
VAS	3.6 ± 0.6	2.0 ± 0.5	1.6	1.2–2.0	9.14	<0.001

Table 6: Comparison of change scores between groups.

Outcome	Δ Group A	Δ Group B	Mean diff.	95% CI	t value	p value
CAIT	6.5 ± 1.2	12.5 ± 1.3	6.0	5.1–6.9	−15.02	<0.001
SEBT	11.1 ± 2.0	18.8 ± 2.2	7.7	6.3–9.1	−12.44	<0.001
FAAM	13.7 ± 2.4	25.9 ± 2.7	12.2	10.6–13.8	−14.89	<0.001
VAS	3.4 ± 0.9	5.1 ± 1.0	1.7	1.1–2.3	7.92	<0.001
MMT	1.0 ± 0.0	2.0 ± 0.0	1.0	–	–	<0.001*

Group B improved significantly more than Group A on every outcome (all $p < 0.001$), with narrow CIs that did not include zero.

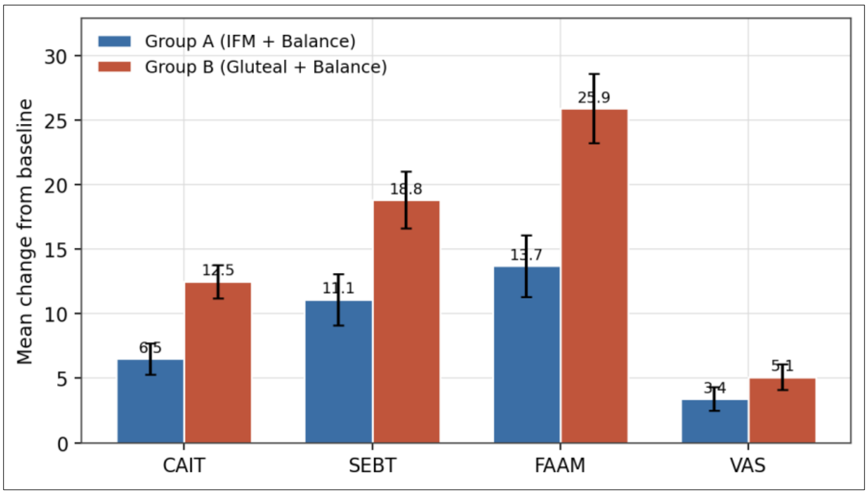

Fig 2: Mean change from baseline by group across outcome measures (error bars = SD).

3.4. Effect sizes and time-by-group interaction

Table 7: Cohen's d effect sizes (within-group and between-group post-treatment).

Outcome	Group A (within) d	Group B (within) d	Between-group (post) d
CAIT	4.48 (very large)	8.62 (extremely large)	5.11 (extremely large)
SEBT	4.11 (very large)	7.37 (extremely large)	3.60 (very large)
FAAM	4.56 (very large)	8.35 (extremely large)	4.62 (extremely large)
VAS	5.23 (extremely large)	7.84 (extremely large)	2.90 (very large)

Repeated-measures ANOVA confirmed highly significant within-group improvement in both groups (all $p < 0.001$), with consistently higher F-values in Group B (e.g., CAIT $F = 412.8$ vs 245.6; FAAM $F = 450.2$ vs 260.1), and a significant time-by-group interaction indicating a steeper recovery trajectory in Group B.

3.5. Responder analysis, adherence, and safety

Table 8: Clinically meaningful responder analysis.

Outcome	Responder criterion	Group A	Group B	Δ %
CAIT	≥ 5-point improvement	14/20 (70%)	19/20 (95%)	+25%
SEBT	≥ 10% improvement	13/20 (65%)	18/20 (90%)	+25%
FAAM	≥ 8-point improvement	15/20 (75%)	20/20 (100%)	+25%
VAS	≥ 2-point reduction	16/20 (80%)	19/20 (95%)	+15%

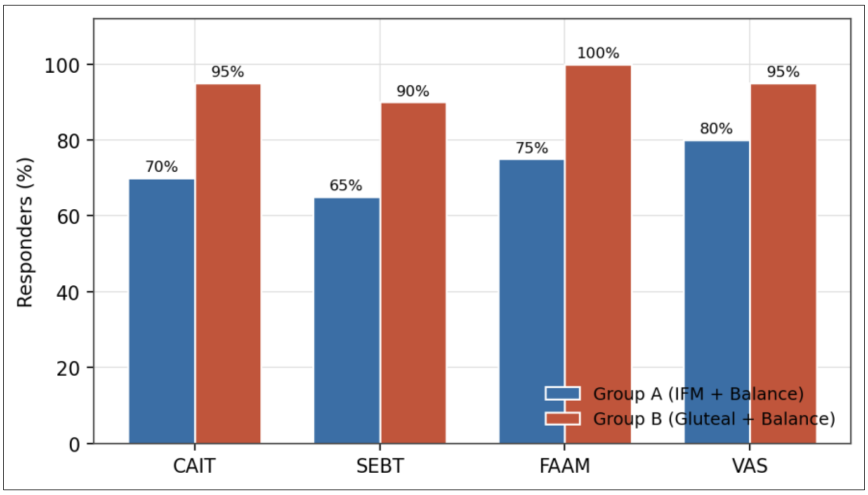

Fig 3: Proportion of clinically meaningful responders by group and outcome.

Adherence was high in both groups (Group A 91–95%; Group B 95–100%). Only mild transient muscle soreness was reported (three cases in Group A, two in Group B); there were no serious adverse events, no exercise intolerance, and no dropouts. Both interventions were therefore safe and well tolerated.

4. Discussion

This study compared intrinsic foot muscle strengthening and gluteal muscle strengthening—each paired with an identical balance-training protocol—in adults with CAI. Both interventions produced significant improvements in ankle stability, dynamic postural control, functional ability, muscle strength, and pain, but gluteal strengthening was consistently superior across every outcome.

The improvement seen in both groups is consistent with neuromuscular re-education and enhanced proprioceptive control. Balance training on unstable surfaces challenges proprioceptive pathways and drives continuous postural corrections, improving the efficiency of feedforward and feedback mechanisms responsible for dynamic joint stability—plausibly explaining the SEBT gains in both groups. The gains in Group A are further explained by the "foot core" concept, in which strengthening the intrinsic foot muscles improves arch stability and distal load distribution, contributing to better CAIT and SEBT scores.

The superiority of Group B supports a kinetic-chain interpretation in which proximal stability governs distal mobility. The gluteal muscles are critical for maintaining lower-limb alignment and pelvic stability during dynamic tasks; strengthening them reduces compensatory movement patterns and improves load transfer across the lower extremity. Because gluteal strengthening transfers readily to closed-chain functional activities such as squatting, stair climbing, and gait, it likely produced the larger FAAM and dynamic-balance gains observed. These findings align with prior work reporting that hip strengthening improves balance and functional performance in CAI and yields better dynamic postural control than isolated balance training.

The magnitude of benefit reinforces clinical relevance: within-group effect sizes were very large to extremely large in both groups, and between-group effect sizes ranged from very large (VAS, SEBT) to extremely large (CAIT, FAAM). Narrow 95% CIs that did not cross zero, a significant time-by-group interaction, and a higher proportion of clinically meaningful responders in Group B together indicate that the superiority of proximal strengthening is both statistically robust and clinically meaningful.

Clinically, these results argue against ankle-only rehabilitation. A proximal-to-distal strategy—progressing from foot-intrinsic activation to integrated hip and lower-limb strengthening, with balance training throughout—may optimise neuromuscular control, reduce sprain recurrence, and improve return-to-function. Gluteal strengthening is simple, low-cost, and feasible as a home programme, making it well suited to busy outpatient settings and resource-limited contexts.

5. Conclusion

Both intrinsic foot muscle strengthening and gluteal muscle strengthening, when combined with balance training, are effective and safe rehabilitation approaches for chronic ankle instability. However, gluteal strengthening combined with balance training is more effective, producing greater improvements in ankle stability (CAIT), dynamic postural control (SEBT), functional ability (FAAM), muscle strength, and pain (VAS). The findings support incorporating proximal (hip/gluteal) strengthening as an essential component of CAI rehabilitation within a kinetic-chain framework, rather than limiting treatment to the ankle alone.

6. Limitations

- Small sample size (n = 40), limiting generalisability.
- Short intervention duration (8 weeks) with no long-term follow-up to assess retention of gains.
- Gender imbalance between groups, a potential minor confounder.
- Absence of participant/therapist blinding, which may introduce performance bias.
- Reliance on subjective functional scales and purposive sampling, which may affect external validity.

Larger, multi-centre trials with longer follow-up and objective measures (e.g., force plates, EMG) are recommended to confirm and extend these findings.

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