Research Article

Changes in Star Excursion Balance Test Performance After Balance Training Alone Versus Combined Balance and Plyometric Training In Recreational Athletes With Functional Ankle Instability

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Abstract

Background: Persistent symptoms and recurrent episodes of giving way after lateral ankle sprain are commonly conceptualized within chronic ankle instability (CAI), a heterogeneous condition involving sensorimotor, mechanical, and perceptual deficits. Evidence supports balance exercise for improving dynamic postural control, but it remains unclear whether adding plyometric exercise provides additional benefit beyond balance training alone.

Objective: To describe changes in Star Excursion Balance Test (SEBT) reach distance after 6 weeks of balance training alone or combined balance and plyometric training in recreationally active men with unilateral functional ankle instability, and to distinguish within-group improvements from evidence of a comparative between-group treatment effect.

Methods: Eighteen recreationally active men with unilateral functional ankle instability (mean age, 22.6 ± 1.8 years) were allocated by a closed-envelope number draw to balance training (n = 9) or combined balance and plyometric training (n = 9). Anterior, posterolateral, and posteromedial SEBT reach distances were measured before and after 6 weeks, and the mean of three successful trials in each direction was analyzed. No formal a priori sample-size calculation was available for review. Because participant-level outcome data and the variance-covariance information required for a valid group-by-time analysis were unavailable, the reported within-group tests were treated as descriptive. An explicitly exploratory sensitivity analysis was then used to reconstruct between-group change estimates from reported summary statistics.

Results: In the balance-training group, posterolateral reach increased from 74.4 to 83.6 cm (+12.4%; p = 0.026), whereas anterior reach changed from 77.8 to 79.1 cm (+1.7%; p = 0.280) and posteromedial reach from 67.8 to 69.2 cm (+2.1%; p = 0.685). In the combined-training group, anterior reach increased from 75.2 to 83.8 cm (+11.4%; p = 0.030), posterolateral reach from 76.3 to 85.4 cm (+11.9%; p = 0.018), and posteromedial reach from 69.3 to 77.5 cm (+11.8%; p = 0.042). Exploratory reconstructed between-group differences in change (combined minus balance) were +7.3 cm for anterior reach (95% CI, approximately -0.4 to 15.0; p approximately 0.061), -0.1 cm for posterolateral reach (95% CI, approximately -9.8 to 9.6; p approximately 0.983), and +6.8 cm for posteromedial reach (95% CI, approximately -3.3 to 16.9; p approximately 0.172).

Conclusion: Posterolateral SEBT reach improved descriptively in both groups, whereas improvements across all three directions were observed only within the combined-training group. However, the available data do not establish that adding plyometric exercise is superior to balance training alone because the original participant-level group-by-time analysis could not be reproduced and the reconstructed comparative estimates were imprecise. These findings should therefore be regarded as hypothesis-generating.

Keywords: ankle sprain; chronic ankle instability; dynamic balance; plyometric exercise; Star Excursion Balance Test.

Introduction

Lateral ankle sprain is a common sports-related musculoskeletal injury with consequences that may extend beyond the acute episode, including recurrent sprain, persistent symptoms, reduced function, and progression to chronic ankle instability (CAI) [1]. A systematic review of active populations estimated CAI prevalence at approximately 25% overall and 46% among people with a previous ankle sprain, while also highlighting substantial heterogeneity related to case definitions and populations [2]. Contemporary models therefore conceptualize CAI as a multidimensional condition involving interacting mechanical, sensorimotor, and perceptual components rather than a single impairment [3].

Current clinical guidance emphasizes structured therapeutic exercise, progressive loading, balance and neuromuscular training, and functional rehabilitation after lateral ankle sprain and in people with persistent instability [4]. At the same time, research validity depends on how instability is defined. International Ankle Consortium criteria recommend a documented history of significant ankle sprain, recurrent giving way and/or recurrent sprain, and validated self-report measures of instability [5]. The present sample was enrolled using functional ankle instability criteria that predated or did not fully implement these contemporary standards; consequently, its findings should not be assumed to apply to all populations meeting current CAI definitions.

Balance training is a central rehabilitation strategy for CAI because it repeatedly challenges sensorimotor integration, postural control, and movement correction. Recent evidence has strengthened this rationale: an umbrella review reported moderate-certainty evidence that balance training improves dynamic postural control, although heterogeneity remains substantial [6], and a 2026 systematic review suggested that effective balance programs tend to use greater cumulative training volume, multiple task types, and progression based on movement quality [7]. Broader exercise-therapy meta-analysis and network meta-analysis also support exercise-based rehabilitation, particularly approaches emphasizing balance and strengthening, while showing that the comparative ranking of specific components remains uncertain [8,9]. Plyometric exercise provides a distinct stimulus through rapid stretch-shortening cycles, landing, and force-attenuation demands; a randomized laboratory study found that both balance and plyometric training can improve neuromuscular-control outcomes in recreational athletes with functional ankle instability [10]. However, these findings do not by themselves establish that adding plyometrics to an otherwise similar balance program produces an incremental clinical benefit.

The SEBT is a functional measure of dynamic postural control that integrates lower-extremity strength, range of motion, proprioception, neuromuscular control, and movement strategy. A contemporary systematic review of 102 studies found generally supportive evidence for SEBT reliability and validity but also wide reliability estimates and population-specific measurement-error thresholds, reinforcing the need for standardized administration and cautious interpretation of change [11]. Reach distance is commonly normalized to limb length to improve comparability across individuals, and test procedures such as practice, stance-foot control, hand position, direction order, and visual feedback can influence performance [11,12]. Therefore, raw centimeter changes should not automatically be interpreted as clinically meaningful, particularly when limb-length normalization and study-specific measurement error are unavailable.

Direct evidence isolating the added value of plyometric exercise beyond balance training remains limited. Accordingly, this study examined pre-to-post changes in three SEBT directions after 6 weeks of balance training alone or combined balance and plyometric training. The primary scientific question is comparative: whether change differs between groups. Separate within-group significance tests cannot answer that question. It was hypothesized that both groups would improve, with larger descriptive gains expected in the combined program; any claim of superiority, however, requires a direct between-group comparison of change with appropriate uncertainty estimates.

Methods

Participants

A convenience sample of 18 recreational athletes with unilateral functional ankle instability were recruited through flyers and posters distributed across Najran University campuses and local sports clubs. Mean age was 22.6 ± 1.8 years, mean height was 174.9 ± 2.5 cm, and mean body mass was 75.6 ± 1.2 kg. Experienced musculoskeletal clinicians screened participants against the eligibility criteria in Table 1. Only participants with unilateral symptoms were included. No formal a priori sample-size calculation was available; with nine participants per group, the study should therefore be regarded as exploratory, particularly for comparative effects. The eligibility criteria captured recurrent sprain and giving-way symptoms but did not include a validated instability questionnaire or all elements of current International Ankle Consortium selection recommendations [5].

Table 1. Eligibility criteria for participants with unilateral functional ankle instability, adapted from Huang et al. [10].

Inclusion criteria	Exclusion criteria
Able to participate in regular exercise.	Pregnancy.
History of at least one acute inversion ankle sprain that resulted in swelling, pain, and functional limitation.	Any neurological disorder that could affect balance.
Recurrent ankle sprain or episodes of the ankle giving way during the preceding 12 months.	Any severe lower-extremity injury that could affect balance.

Inclusion criteria	Exclusion criteria
Negative anterior drawer and talar tilt tests on clinical examination.	An ankle sprain within 7 days before testing.

All participants completed at least 3 hours of sport or exercise per week. Before enrollment, they received written and verbal information about the study purpose and procedures and provided written informed consent. The Najran University Research Ethics Committee approved the study (reference 442-42-6851-D). Participants were allocated by drawing a number from a closed envelope: 1 indicated balance training alone, and 2 indicated combined balance and plyometric training.

Procedures

Star Excursion Balance Test

SEBT procedures were based on established descriptions of the test and were broadly consistent with the construct assessed by contemporary standardized protocols [11]. Before testing, participants completed a 5-minute cycle-ergometer warm-up and three practice trials in each direction to reduce learning effects. The injured limb served as the stance limb. With their hands on their hips, participants reached with the uninjured limb along taped anterior, posterolateral, and posteromedial lines while keeping the stance foot in contact with the floor. Because visual feedback can alter SEBT performance [12], the absence of a formally standardized visual-feedback procedure is relevant to reproducibility.

For posterolateral reach, the reaching limb moved backward and away from the stance limb; for posteromedial reach, it moved backward and toward the stance limb.

Directions were tested in a fixed order: anterior, posterolateral, then posteromedial. At least 2 minutes of rest was provided between trial sets to limit fatigue. Using a fixed rather than randomized direction sequence improves procedural consistency within this study but does not eliminate possible order or learning effects; future protocols should prespecify and justify sequence handling in accordance with a standardized SEBT procedure [11].

Participants reached as far as possible, lightly touched the tape with the forefoot without using it for support, and returned to the starting position under control (Figure 1). Reach distance was measured manually in centimeters, and the mean of three successful trials was used for analysis. Reach distances were analyzed as raw centimeters rather than normalized to limb length. This is an important methodological limitation because normalization is commonly used to reduce anthropometric influence and facilitate comparison across individuals and studies [11].

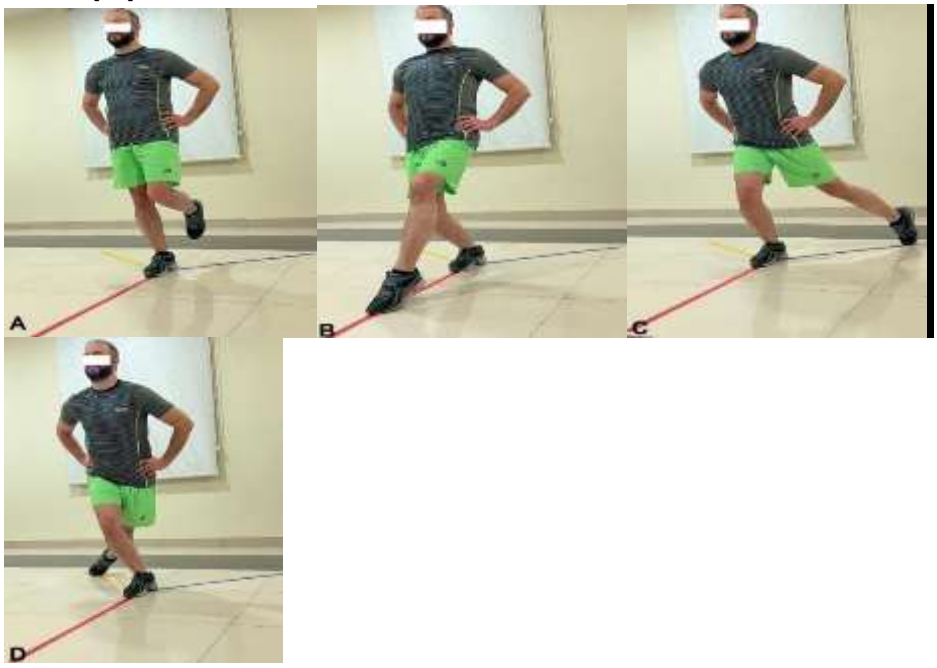


Figure 1. SEBT setup: (a) starting position; (b) anterior reach; (c) posterolateral reach; and (d) posteromedial reach.

Training Protocol

Participants completed a 6-week program of balance training alone or combined balance and plyometric training (Table 2). A minimum attendance of two-thirds of scheduled sessions was required for inclusion in the analysis. Each session began with a 5-minute warm-up, and a researcher instructed participants and supervised the program. The 6-week duration is consistent with the time frame used in many effective balance-rehabilitation programs; however, recent evidence indicates that total training volume, session frequency and duration, task variety, and progression rules are important intervention descriptors [7]. In the present dataset, detailed information on session frequency and duration, repetitions, sets, rest intervals, progression criteria, actual attendance, protocol deviations, and adverse events was unavailable. These omissions prevent full replication of the intervention and assessment of treatment dose or fidelity.

Table 2. Six-week balance and combined balance-plyometric training programs.

Period	Balance-training group	Combined balance-plyometric group
Week 1-2	Balance squat Balance dribble	Squat jumps Balance squat Balance dribble Forward zigzag jumps Lateral sawtooth jumps
Week 3-4	Balance lunge (1 ankle disc) Balance ball catch	Split-squat jumps Balance lunge (1 ankle disc) Forward zigzag hops Tuck jumps Balance ball catch
Week 5-6	Balance lunge (2 ankle discs) Balance ball roll	Cycled split-squat jumps Target hops Forward barrier jumps Balance lunge (2 ankle discs) Balance ball roll Drop jumps

Statistical Analysis

Analyses were conducted using SPSS version 25 (IBM Corp., Armonk, NY, USA). For each SEBT direction, the mean of three successful trials was analyzed. For a two-group pre-post design, the appropriate comparative analysis is the group-by-time interaction from a mixed model/repeated-measures analysis, or an equivalent direct comparison of change scores. Participant-level SEBT observations, pre/post standard deviations, and the within-participant covariance required to reproduce such an analysis were unavailable. The reported within-group p values were therefore retained only as descriptive secondary information and were not used to infer comparative efficacy. For a transparent exploratory sensitivity analysis, the standard deviation of each change score was approximately reconstructed from the reported mean change, two-sided paired-test p value, $n = 9$, and $df = 8$; reconstructed change scores were then compared between groups with Welch independent-samples t tests and 95% confidence intervals. Because the source p values were rounded, these estimates are approximate, are not substitutes for analysis of the original participant-level data, and should not be treated as confirmatory results. Six within-group tests were reported without multiplicity adjustment; accordingly, their nominal p values should be interpreted cautiously and emphasis placed on effect estimates and uncertainty rather than dichotomous significance.

Results

All 18 participants completed the intervention (9 per group). Sixteen used the right injured limb and two the left injured limb as the stance limb. The groups were similar descriptively in age and height, whereas mean body mass was higher in the combined-training group (76.2 ± 1.1 kg) than in the balance-training group (73.8 ± 1.9 kg). With only nine participants per group, even modest baseline imbalances may influence change estimates; baseline characteristics are therefore presented descriptively rather than subjected to significance testing (Table 3).

Table 3. Baseline participant characteristics by training group.

Characteristic	Balance training (B)	Balance + plyometric training (BP)
Sex	Male, n = 9	Male, n = 9
Age (yr)	22.9 ± 1.4	22.3 ± 1.7
Height (cm)	175.1 ± 2.2	173.7 ± 4.8
Mass (kg)	73.8 ± 1.9	76.2 ± 1.1

B, balance-training group.
BP, combined balance and plyometric training group.

In the balance-training group, posterolateral reach increased by 9.2 cm (12.4%), from 74.4 to 83.6 cm (p = 0.026). Anterior reach increased by 1.3 cm (1.7%; p = 0.280) and posteromedial reach by 1.4 cm (2.1%; p = 0.685) (Table 4). These unadjusted within-group p values are descriptive and should not be interpreted as evidence that the balance-only program differs from the combined program.
In the combined-training group, anterior reach increased by 8.6 cm (11.4%; 75.2 to 83.8 cm; p = 0.030), posterolateral reach by 9.1 cm (11.9%; 76.3 to 85.4 cm; p = 0.018), and posteromedial reach by 8.2 cm (11.8%; 69.3 to 77.5 cm; p = 0.042). In the exploratory summary-statistic reconstruction, the estimated between-group difference in change (combined minus balance) was +7.3 cm for anterior reach (95% CI, approximately -0.4 to 15.0; p approximately 0.061), -0.1 cm for posterolateral reach (95% CI, approximately -9.8 to 9.6; p approximately 0.983), and +6.8 cm for posteromedial reach (95% CI, approximately -3.3 to 16.9; p approximately 0.172). The wide confidence intervals indicate substantial uncertainty, particularly for anterior and posteromedial reach, and the reconstructed analysis provides no clear evidence that change differed between groups.

Table 4. Mean SEBT reach distance before and after balance training alone and combined balance-plyometric training.

Training Group	Anterior Direction			Posterolateral Direction			Posteromedial Direction		
	Pre	Post	p value	Pre	Post	p value	Pre	Post	p value
B (cm)	77.8	79.1	0.280	74.4	83.6	0.026*	67.8	69.2	0.685
BP (cm)	75.2	83.8	0.030*	76.3	85.4	0.018*	69.3	77.5	0.042*

B, balance-training group.
BP, combined balance and plyometric training group.
cm, centimeters.
Pre, pretraining.
Post, post-training.
*Within-group p ≤ 0.05.

Discussion

This study examined SEBT performance after 6 weeks of balance training alone or combined balance and plyometric training in recreationally active men with unilateral functional ankle instability. Posterolateral reach improved descriptively by about 9 cm in both groups, whereas anterior and posteromedial gains were larger in the combined-training group. The central finding is not that one program was statistically superior: the original participant-level group-by-time analysis was unavailable, and the exploratory reconstructed between-group estimates were imprecise and crossed the null for all three directions. The most defensible interpretation is therefore that both interventions were associated with directional improvements, while the incremental effect of adding plyometric exercise remains uncertain.
The posterolateral improvement is consistent with the broader rehabilitation literature. Recent meta-analyses show that balance and exercise-based interventions can improve dynamic postural-control outcomes in CAI, including SEBT measures, although between-study heterogeneity is substantial [6,8,13]. The 2026 umbrella review judged the evidence for improvement in dynamic postural control to be of moderate certainty [6], while

a 2026 review of balance-exercise parameters suggested that programs with greater cumulative volume, multiple balance tasks, and progression based on movement quality tend to be more successful [7]. These findings support the plausibility of improvement over 6 weeks, but they also expose an important limitation of the present study: frequency, session duration, repetitions, sets, progression criteria, and actual adherence were not sufficiently documented to determine whether the delivered dose resembled currently supported protocols. The larger descriptive anterior and posteromedial changes in the combined-training group are biologically plausible because plyometric training adds rapid force production, landing control, and repeated stretch-shortening-cycle demands. Huang et al. reported neuromuscular-control improvements after balance and plyometric interventions in recreational athletes with functional ankle instability [10], and hop-stabilization training has been shown to modify landing biomechanics in athletes with CAI [14]. Nevertheless, plausibility should not be confused with comparative efficacy. A recent network meta-analysis identified balance- and strengthening-focused interventions as effective components of CAI management but did not establish a general superiority of adding plyometrics to balance training [9]. In the present data, posterolateral change was virtually identical between groups (9.2 vs 9.1 cm), and the comparative confidence intervals for anterior and posteromedial change were wide. Thus, the pattern generates a testable hypothesis for a larger trial rather than evidence of an additive plyometric effect.

Several limitations materially constrain interpretation. First, the sample was small, male-only, recruited by convenience, and lacked a non-exercise control group; no a priori sample-size calculation was available, so precision and statistical power for between-group effects were not prospectively established. Second, participant selection did not include a validated instability questionnaire and did not fully align with International Ankle Consortium criteria [5], limiting generalizability to contemporary CAI populations. Third, allocation used closed envelopes, but sequence generation, envelope opacity, sequential numbering, tamper resistance, and the individuals responsible for generating and implementing the allocation were not documented; therefore, the risk of selection bias cannot be fully assessed. Blinding of the outcome assessor and analyst was also not reported. Fourth, SEBT direction order was fixed, visual-feedback procedures were not standardized, and reach was reported in raw centimeters rather than normalized to limb length. A contemporary psychometric review emphasizes standardized SEBT procedures and shows that reliability and measurement-error thresholds vary across populations [11]; therefore, the observed centimeter changes cannot automatically be classified as clinically important. Fifth, intervention frequency, duration, volume, progression, adherence, protocol deviations, and adverse events were incompletely documented, limiting reproducibility and dose-response interpretation. Finally, the original participant-level outcome data and covariance structure were unavailable, preventing verification of the appropriate group-by-time analysis. The reconstructed sensitivity analysis relies on rounded p values and should be considered hypothesis-generating only. Future trials should preregister a primary outcome, use contemporary CAI eligibility criteria, conceal allocation rigorously, normalize reach to limb length, standardize SEBT administration, document intervention fidelity and adverse events, and report participant-level-compatible effect estimates with 95% confidence intervals.

Conclusion

After 6 weeks, posterolateral SEBT reach increased descriptively by approximately 9 cm in both groups, while larger anterior and posteromedial gains were observed in the combined balance-plyometric group. These patterns are compatible with contemporary evidence that exercise-based rehabilitation can improve dynamic postural control in ankle instability, but this study does not establish that adding plyometric exercise is superior to balance training alone. The absence of original participant-level data, small sample, non-normalized SEBT outcomes, incomplete intervention-dose reporting, and imprecise reconstructed between-group estimates require cautious interpretation. The results are best viewed as hypothesis-generating evidence for a larger, adequately powered trial with standardized CAI eligibility criteria, normalized SEBT outcomes, complete intervention-fidelity reporting, and a prespecified group-by-time analysis.

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