

Effect of Core Stability Training on Balance and Physical Performance in Football Players

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Abstract

Background: Core stability is theorised to underpin lumbopelvic control, postural stability and efficient force transfer along the kinetic chain during football-specific movement. However, most primary studies have measured either balance or physical performance in isolation, and few have assessed both concurrently within a single cohort of adult football players, leaving the assumed mechanistic link between proximal neuromuscular control and downstream athletic performance insufficiently tested.

Objectives: To determine the effect of an eight-week structured core stability training programme, added to standard football training, on static balance, dynamic balance and selected physical performance parameters in football players, and to compare the magnitude of change against standard football training alone.

Methods: A two-arm, parallel-group, assessor-blinded randomized controlled trial was conducted in 60 football players aged 18–26 years competing at college/university, district or state level. Participants were randomly allocated 1:1 using a computer-generated sequence with sequentially numbered, opaque, sealed envelopes to an Experimental group (n = 30; progressive core stability training, three supervised sessions per week for eight weeks, in addition to standard football training) or a Control group (n = 30; standard football training alone). The primary outcome was dynamic balance (Y Balance Test composite reach score, %). Secondary outcomes were static balance (Single-Leg Stance Test, eyes closed), countermovement vertical jump height, 20-metre sprint time and 505 change-of-direction time, assessed at baseline and at week 8. Within-group change was analysed using the paired t-test, between-group difference in mean change using the independent-samples t-test, and effect size using Cohen's d, with significance set at $p < 0.05$.

Results: All 60 participants completed the trial with no loss to follow-up; mean adherence in the Experimental group was $92.2 \pm 4.7\%$. Both groups improved significantly on all five outcomes ($p < 0.001$). Between-group differences in mean improvement favoured the Experimental group throughout: Y Balance Test composite score 4.28% (6.09 ± 1.47 versus 1.81 ± 1.44 ; $d = 2.94$), static balance 0.57 s ($d = 2.86$), vertical jump 1.82 cm ($d = 2.21$), 20-metre sprint 0.09 s ($d = 3.19$) and 505 change-of-direction time 0.13 s ($d = 2.56$), all $p < 0.001$.

Conclusion: An eight-week structured, criterion-progressed core stability programme delivered as an adjunct to standard football training produced significantly greater improvement in static balance, dynamic balance, vertical jump, linear sprint and change-of-direction performance than standard football training alone. The consistency of benefit across all five outcome domains supports core stability training as a time-efficient supplement to, rather than a replacement for, conventional football conditioning. Injury incidence was not measured, so no inference regarding injury prevention can be drawn.

Keywords: core stability; football; soccer; postural balance; Y Balance Test; athletic performance; change of direction; randomized controlled trial.

1. Introduction

Competitive football imposes intermittent, high-intensity physical demands in which players repeatedly accelerate, decelerate, change direction, jump, land on a single limb and make contact with opponents, frequently under conditions of accumulating fatigue and within an unpredictable, ball- and opponent-driven environment.^{1,2} Effective execution of these actions depends on the ability to maintain and rapidly restore postural control while simultaneously generating and absorbing force through the lower limbs. Postural control in athletes is not a fixed trait but a trainable capacity that adapts to sport-specific and neuromuscular stimuli,³ and it emerges from the integration of visual, vestibular and somatosensory information into coordinated motor output.⁴ Expertise and prior training history themselves shape the postural control strategies adopted by football players, particularly the degree of reliance on visual input.⁵

Balance is of interest not only for performance but also for injury risk. Dynamic balance deficits assessed using star-excursion-type reach tests have been prospectively associated with non-contact lower-extremity injury in athletic populations,^{6,15} and injury-prevention programmes that incorporate balance training reduce ankle injury rates in soccer players specifically.⁸ Proprioceptive afference from muscle spindles, Golgi tendon organs and joint receptors provides the continuous positional information on which single-limb postural equilibrium depends,⁷ making trunk and hip neuromuscular training a plausible route to improved balance.

The theoretical basis for targeting the trunk derives from the concept of core stability, defined as the capacity of the lumbopelvic-hip complex to maintain control and alignment during static and dynamic tasks through coordinated activity of the trunk, abdominal, spinal, pelvic and hip musculature.⁹ Bergmark's mechanical model of the lumbar spine distinguished local stabilising musculature from global force-producing musculature,¹⁰ Panjabi described spinal stability as the product of interacting passive, active and neural control subsystems,¹¹ and Hodges and Richardson demonstrated that inefficient stabilisation of the lumbar spine is associated with altered motor control of transversus abdominis.¹² Kibler and colleagues extended these principles to sport through the kinetic-chain model, in which a controlled proximal trunk provides the base from which force is generated, transferred and dissipated through the limbs.¹³ Sensory-motor control is now understood to be integral rather than incidental to this stabilising function.¹⁴

The empirical evidence for translating these principles into measurable athletic benefit is substantial but uneven. Recent systematic reviews and meta-analyses in soccer players report significant pooled improvement in physical performance¹⁶ and in balance outcomes¹⁷ following core stability training, whereas a meta-analysis focused specifically on speed reported no significant pooled effect on 20-metre or 30-metre sprint times.¹⁸ Earlier syntheses of isolated versus integrated core training in mixed athletic populations reached similarly cautious conclusions,¹⁹ while scoping work has highlighted marked heterogeneity in intervention protocols and, frequently, insufficient reporting of exercise content, progression and dosage.²⁰ Controlled trials in soccer have reported improvement in postural balance after a 12-week programme²¹ and improved fitness and skill performance after proprioceptive training in young players,²² and core stability training has been shown to improve lower-limb balance strength³¹ and neuromuscular and athletic performance in elite youth soccer, particularly under unstable conditions.³²

Three gaps persist. First, and most importantly, the majority of primary studies measure either balance or physical performance, rarely both within the same cohort. This matters because the case for core stability training as a performance strategy rests on the premise that improved proximal control transfers distally; concurrent assessment of both domains is required before that premise can be evaluated empirically. Second, adult players competing at collegiate and district level are under-represented relative to youth and elite samples, despite occupying a population in which core stability deficits are plausible, consequential and amenable to intervention. Third, the sprint-specific literature remains equivocal,^{18,25,26} raising the unresolved question of whether the exercise content and progression of a given programme, rather than core training per se, determines transfer to linear speed.

The present trial was therefore designed to determine the effect of an eight-week structured, criterion-progressed core stability training programme, added to standard football training, on static balance, dynamic balance, vertical jump, 20-metre sprint and change-of-direction performance assessed concurrently in adult football players, and to compare the magnitude of change against an active comparator of standard football training alone. It was hypothesised that the Experimental group would demonstrate significantly greater improvement than the Control group across all outcome domains.

2. Materials and Methods

2.1 Study design and setting

This was a two-arm, parallel-group, assessor-blinded randomized controlled trial with a 1:1 allocation ratio, conducted at the Institute of Applied Medicines and Research (IAMR), Ghaziabad, Uttar Pradesh, India, in association with the football training facilities used by the participating players. All assessments were performed in a dedicated testing area with consistent flooring, lighting and equipment, and every outcome measure was recorded by the same assessor at both time points. The Control group received an active comparator — standard football training alone — rather than no intervention, so that the additional effect attributable to core stability training could be distinguished from adaptation arising from routine training and match exposure over the same period.

2.2 Ethical approval and consent

Ethical approval was obtained from the Institutional Ethics Committee of the Institute of Applied Medicines and Research, Ghaziabad, before commencement of recruitment. The study was conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from every participant after the purpose, procedures, anticipated benefits, potential risks and the voluntary nature of participation had been explained in a language the participant understood. Participant data were coded throughout, participants retained the right to withdraw at any stage without penalty, and any adverse event occurring during testing or training was documented and managed.

2.3 Participants and eligibility criteria

Adult football players aged 18–26 years who were training and competing regularly at college/university, district or state level were recruited by purposive sampling. Inclusion criteria were: age 18–26 years; active participation in football training and/or competition on a minimum of three sessions per week at one of the stated competitive levels; willingness to complete the full eight-week programme and both assessment sessions; ability to understand and follow verbal and written instruction; medical fitness for moderate-to-high intensity physical activity; and provision of written informed consent.

Exclusion criteria were: current musculoskeletal injury limiting football participation or physical testing; lower-limb injury or surgery within the preceding six months; neurological or vestibular disorder affecting balance; cardiovascular or systemic condition contraindicating moderate-to-high intensity exercise; concurrent participation in another structured core stability or balance training programme; inability to complete baseline testing; and any medical condition judged by the investigator to render participation unsafe.

2.4 Sample size

Sixty participants who satisfied the eligibility criteria were enrolled and allocated equally to the two groups ($n = 30$ per group). This sample size is consistent with comparable randomized controlled trials evaluating core stability training on balance and physical performance outcomes in football and other field-sport populations. The a priori sample-size calculation on record with the institutional ethics committee was based on the primary outcome (Y Balance Test composite reach score), a two-sided significance level of $\alpha = 0.05$ and statistical power of 80%.

2.5 Randomization, allocation concealment and blinding

After screening, provision of written informed consent and completion of baseline assessment, eligible participants were randomly allocated to the Experimental or Control group in a 1:1 ratio using a computer-generated random sequence. Allocation concealment was maintained using sequentially numbered, opaque, sealed envelopes prepared by a member of the research team not involved in outcome assessment, and opened only after baseline testing had been completed. Blinding of participants and of the training instructor was not feasible, because the additional exercise programme was necessarily apparent to both. The outcome assessor responsible for recording all five outcome measures was blinded to group allocation at baseline and at week 8.

2.6 Outcome measures

The primary outcome was dynamic balance, quantified by the Y Balance Test composite reach score. Secondary outcomes were static balance, countermovement vertical jump height, 20-metre sprint time and 505 change-of-direction time. All outcomes were recorded at baseline and at the end of week 8 using identical equipment, testing order, limb selection and assessor.

2.6.1 Dynamic balance — Y Balance Test (primary outcome). Participants stood on the stance limb at the centre of the Y Balance Test kit and reached with the free limb as far as possible along the anterior, posteromedial and posterolateral directions in turn, maintaining single-leg stance and returning to the start position between reaches without loss of balance. Reach distance in each direction was recorded to the nearest 0.5 cm after one practice trial, with three recorded trials per direction and 15–30 s of rest between trials. The composite score was calculated as the sum of the three directional reach distances divided by three times the participant's limb length, expressed as a percentage. The same stance limb and limb-length measurement were used at both time points.

2.6.2 Static balance — Single-Leg Stance Test (eyes closed). Participants stood barefoot on a firm, level surface with hands on the hips and raised the non-stance limb to approximately 90° of knee flexion without contact with the stance limb. Timing began when the eyes were closed on the assessor's signal and stopped when the participant opened the eyes, used the raised limb or arms for support, or moved the stance foot. Testing was performed on the preferred kicking-support limb, with one practice trial followed by two recorded trials separated by 60 s of rest; the better of the two trials, in seconds, was analysed.

2.6.3 Vertical jump — countermovement jump. Participants stood side-on to a wall-mounted jump board, reached upward to mark standing reach height, then performed a countermovement jump with self-selected squat depth and free arm swing. Jump height was the difference between standing reach and jump-touch height, in centimetres. After one practice trial, three maximal-effort trials were performed with 30–45 s of rest between trials, and the best trial was analysed.

2.6.4 Linear sprint — 20-metre sprint test. Sprint performance was assessed on a flat outdoor track using electronic timing gates at the start and 20-metre marks. Participants began from a standardised standing start 0.5 m behind the first gate and sprinted maximally through the finish gate. After one submaximal practice trial, two maximal-effort trials were performed with a minimum of 3 min recovery, and the faster trial, in seconds, was analysed.

2.6.5 Change of direction — 505 test. Participants sprinted from a standing start through a 15-metre approach, crossed a timing gate positioned 5 m before a marked turning line, planted and turned 180° at the line, and sprinted back through the same gate; time was recorded electronically over the final 10-metre out-and-back segment. Testing was performed off the preferred turning limb. After one practice trial, two maximal-effort trials were performed with a minimum of 3 min recovery, and the faster trial, in seconds, was analysed.

2.7 Intervention

Participants allocated to the Experimental group completed a structured, progressive core stability training programme in addition to their standard football training, delivered over eight weeks at three supervised sessions per week (24 sessions in total), with each session lasting approximately 25–30 minutes. The programme advanced in two-week blocks from basic trunk activation and control, through core endurance and stability, to dynamic and anti-rotation control, and finally to functional, football-specific core control (Table 1). Progression to the next phase was permitted only once the participant demonstrated adequate technique and movement control at the current exercise level, in keeping with a criterion-based rather than time-based progression model. The FITT parameters of the programme are summarised in Table 2.

Participants allocated to the Control group continued their previously established football training over the same eight-week period without the additional core stability programme. Standard football training for both groups comprised routine technical, tactical and conditioning sessions organised by the participants' respective teams, typically four to five sessions per week; this schedule was documented but not modified for either group. Control participants were asked not to commence any additional structured core stability or balance training during the study period.

Attendance at every core stability session was recorded for the Experimental group, together with exercises completed, sets and repetitions performed, exercise progression and any adverse response. Adherence was calculated for each participant as the percentage of the 24 prescribed sessions attended.

Table 1. Eight-week progressive core stability training protocol (Experimental group).

Weeks	Phase and exercise content	Sets	Reps / hold	Rest	Progression criterion
1–2	Basic activation and control: diaphragmatic bracing, dead bug, bird-dog, basic bridge, modified front plank	2–3	8–10 reps / 20–30 s hold	30–45 s	Basic → controlled execution with neutral spine
3–4	Core endurance and stability: full front plank, side plank, bridge progression, bird-dog and dead bug progression	3	10–12 reps / 30–45 s hold	30–45 s	Increase hold duration and repetitions
5–6	Dynamic and anti-rotation control: Pallof press, rotational side plank, single-leg bridge with march, dynamic plank with shoulder taps	3	8–12 reps / 20 taps	45–60 s	Increase movement challenge and range
7–8	Functional and sport-specific core control: standing anti-rotation in single-leg stance, multidirectional	3	6–10 reps per side	45–60 s	Progress to functional football-specific tasks

Weeks	Phase and exercise content	Sets	Reps / hold	Rest	Progression criterion
	single-leg reach, squat-to-lunge core control, acceleration–deceleration drills, football-movement integration				

All sessions were supervised and delivered three times per week for eight weeks (24 sessions), each lasting approximately 25–30 minutes, in addition to standard football training.

Table 2. FITT parameters of the core stability training programme.

FITT component	Prescription
Frequency	Three supervised sessions per week for eight weeks (24 sessions in total)
Intensity	Criterion-based progression from basic controlled activation to dynamic, anti-rotation and functional football-specific core control
Time	Approximately 25–30 minutes per session
Type	Progressive core stability exercises: trunk activation drills, plank and bridge variations, anti-rotation and dynamic stability exercises, and functional football-specific core control drills

2.8 Statistical analysis

Data were analysed using SPSS. Descriptive statistics (mean and standard deviation for continuous variables; frequency and percentage for categorical variables) were used to summarise demographic and outcome data. Normality of continuous variables was assessed using the Shapiro–Wilk test. Baseline continuous variables were compared between groups using the independent-samples t-test and baseline categorical variables using the chi-square test. Within-group change from baseline to week 8 was assessed using the paired t-test, and between-group differences in mean change were assessed using the independent-samples t-test. Effect size for each between-group comparison was calculated as Cohen’s *d* and interpreted using conventional thresholds (0.2 small, 0.5 moderate, 0.8 large). Statistical significance was set at $p < 0.05$ throughout, and all analyses were conducted on the complete dataset of 60 participants.

3. Results

3.1 Participant flow and baseline characteristics

Sixty players were enrolled, randomised and analysed, with no loss to follow-up and no protocol deviation in either arm (Figure 1). Mean adherence to the prescribed 24 core stability sessions in the Experimental group was $92.2 \pm 4.7\%$. No adverse events attributable to the intervention were recorded.

The groups were comparable at baseline for age (21.37 ± 1.87 versus 21.57 ± 2.06 years, $p = 0.695$), body mass index, years of football experience, weekly training frequency, playing position, competitive level and baseline scores on all five outcome measures ($p > 0.05$ for all). Participants in both groups were distributed across college/university, district and state levels in comparable proportions, and defenders and midfielders together accounted for the majority of the sample, consistent with the typical positional composition of a football squad. Randomisation produced a chance imbalance in sex distribution, with 28 of 30 male participants in the Experimental group compared with 22 of 30 in the Control group. Baseline characteristics are presented in Table 3.

Table 3. Baseline demographic and clinical characteristics of the two groups (n = 60).

Characteristic	Experimental (n = 30)	Control (n = 30)	Total (N = 60)
Age, mean $\pm$ SD (years)	21.37 ± 1.87	21.57 ± 2.06	21.47 ± 1.96
Age group 18–20 years, n	8	10	18

Characteristic	Experimental (n = 30)	Control (n = 30)	Total (N = 60)
Age group 21–22 years, n	14	9	23
Age group 23–24 years, n	5	10	15
Age group 25–26 years, n	3	1	4
Sex — male, n	28	22	50
Sex — female, n	2	8	10
Position — defender, n	10	9	19
Position — midfielder, n	9	11	20
Position — forward, n	9	4	13
Position — goalkeeper, n	2	6	8
Level — college/university, n	12	12	24
Level — district, n	10	12	22
Level — state, n	8	6	14

SD, standard deviation. Between-group comparison of mean age was non-significant ($p = 0.695$); baseline outcome scores did not differ significantly between groups ($p > 0.05$ for all).

3.2 Within-group changes

Both groups improved significantly from baseline to week 8 on all five outcome measures ($p < 0.001$ for every comparison). In the Experimental group, static balance increased from 7.24 ± 0.82 s to 7.97 ± 0.78 s, Y Balance Test composite score from $87.88 \pm 5.07\%$ to $93.97 \pm 5.14\%$, vertical jump height from 43.10 ± 2.75 cm to 45.85 ± 3.06 cm, 20-metre sprint time decreased from 3.35 ± 0.11 s to 3.22 ± 0.11 s, and 505 change-of-direction time decreased from 4.96 ± 0.20 s to 4.78 ± 0.21 s (Table 4).

The Control group also improved significantly on every measure, but the magnitude of change was consistently smaller: static balance increased from 7.29 ± 0.74 s to 7.46 ± 0.77 s, Y Balance Test composite score from $87.34 \pm 4.59\%$ to $89.15 \pm 4.52\%$, vertical jump height from 42.95 ± 2.38 cm to 43.88 ± 2.55 cm, 20-metre sprint time decreased from 3.37 ± 0.12 s to 3.34 ± 0.12 s, and change-of-direction time decreased from 4.99 ± 0.17 s to 4.94 ± 0.17 s (Table 5).

Table 4. Within-group comparison of pre- and post-intervention outcome scores in the Experimental group (n = 30).

Outcome measure	Pre-intervention (mean $\pm$ SD)	Post-intervention (mean $\pm$ SD)	t-value	p-value
Static balance (s)	7.24 ± 0.82	7.97 ± 0.78	19.43	< 0.001
Y Balance Test composite (%)	87.88 ± 5.07	93.97 ± 5.14	22.67	< 0.001
Vertical jump (cm)	43.10 ± 2.75	45.85 ± 3.06	20.11	< 0.001
20-metre sprint (s)	3.35 ± 0.11	3.22 ± 0.11	23.50	< 0.001
505 change of direction (s)	4.96 ± 0.20	4.78 ± 0.21	18.59	< 0.001

Paired t-test. SD, standard deviation. For sprint and change-of-direction time, a lower post-intervention value indicates improved performance.

Table 5. Within-group comparison of pre- and post-intervention outcome scores in the Control group (n = 30).

Outcome measure	Pre-intervention (mean ± SD)	Post-intervention (mean ± SD)	t-value	p-value
Static balance (s)	7.29 ± 0.74	7.46 ± 0.77	4.90	< 0.001
Y Balance Test composite (%)	87.34 ± 4.59	89.15 ± 4.52	6.87	< 0.001
Vertical jump (cm)	42.95 ± 2.38	43.88 ± 2.55	5.69	< 0.001
20-metre sprint (s)	3.37 ± 0.12	3.34 ± 0.12	8.20	< 0.001
505 change of direction (s)	4.99 ± 0.17	4.94 ± 0.17	5.47	< 0.001

Paired t-test. SD, standard deviation.

3.3 Between-group comparison

The Experimental group achieved significantly greater mean improvement than the Control group on all five outcome measures ($p < 0.001$ for every comparison), with effect sizes in the large-to-very-large range (Cohen's d 2.21–3.19). The between-group difference in mean improvement was 0.57 s for static balance, 4.28 percentage points for the Y Balance Test composite score, 1.82 cm for vertical jump height, 0.09 s for 20-metre sprint time and 0.13 s for 505 change-of-direction time. The largest effect sizes were observed for 20-metre sprint time ($d = 3.19$) and the Y Balance Test ($d = 2.94$), and the smallest for vertical jump height ($d = 2.21$). Between-group results are presented in Table 6.

Table 6. Between-group comparison of mean improvement from baseline to week 8.

Outcome measure	Experimental Δ (mean ± SD)	Control Δ (mean ± SD)	t-value	p-value	Cohen's d
Static balance (s, increase)	0.74 ± 0.21	0.17 ± 0.19	11.06	< 0.001	2.86
Y Balance Test composite (% increase)	6.09 ± 1.47	1.81 ± 1.44	11.37	< 0.001	2.94
Vertical jump (cm, increase)	2.75 ± 0.75	0.93 ± 0.90	8.54	< 0.001	2.21
20-metre sprint (s, reduction)	0.13 ± 0.03	0.04 ± 0.03	12.36	< 0.001	3.19
505 change of direction (s, reduction)	0.18 ± 0.05	0.05 ± 0.05	9.93	< 0.001	2.56

Independent-samples t-test on change scores. Δ , mean change from baseline to week 8; SD, standard deviation. For sprint and change-of-direction outcomes, Δ represents reduction in time, so a larger value indicates greater improvement.

Figure 1. CONSORT-style participant flow diagram.

[Insert participant flow diagram: assessed for eligibility → randomised (n = 60) → allocated to Experimental group (n = 30) and Control group (n = 30) → received allocated intervention (n = 30 per group) → lost to follow-up (n = 0 per group) → analysed (n = 30 per group).]

4. Discussion

The principal finding of this trial is that an eight-week structured, criterion-progressed core stability programme delivered as an adjunct to standard football training produced significantly greater improvement than standard football training alone across every outcome domain assessed — static balance, dynamic balance, vertical jump, linear sprint and change of direction — with large-to-very-large effect sizes. Because the Control group also improved significantly on all five measures, these results additionally demonstrate that routine football training alone generates measurable adaptation over eight weeks, and that the incremental benefit of the core stability programme is best interpreted as an addition to, rather than a substitute for, that baseline stimulus.

4.1 Balance outcomes

The improvement in Y Balance Test composite score in the Experimental group aligns with meta-analytic evidence that core stability training significantly improves dynamic balance in soccer players,¹⁷ with the significant gains in postural balance reported by Chaari et al. following a 12-week core stability programme in soccer players with groin pain,²¹ and with the improved fitness and skill performance reported after proprioceptive exercise training in young players.²² Neuromuscular training incorporating balance and trunk-control components has likewise been shown to improve Star Excursion Balance Test performance, a test closely related to the Y Balance Test, in young athletes,²⁸ providing external support for the direction, though not necessarily the magnitude, of the present finding.

Two mechanisms plausibly account for the balance gains. Mechanically, the lumbopelvic-hip complex functions as a stabilising unit that supplies a controlled base from which the limbs generate and transfer force,^{11,13} so improved trunk control should directly reduce the postural perturbation associated with single-limb reaching. Sensorimotor mechanisms are likely to contribute in parallel: proprioceptive afference from trunk and hip musculature supplies the central nervous system with the positional information required to maintain equilibrium during single-leg stance,⁷ and repeated practice of controlled trunk stabilisation tasks may refine that feedback loop. Inefficient stabilisation of the trunk musculature is associated with impaired motor control at the lumbar spine and pelvis,¹² and postural control has been shown to be highly trainable in athletic populations,³ consistent with the substantial static balance gains observed here.

The clinical relevance of the dynamic balance improvement warrants comment. Reach-test performance is prospectively associated with non-contact lower-extremity injury risk in athletes,^{6,15} and injury-prevention programmes incorporating balance training reduce ankle injury rates in soccer specifically.⁸ A 6.09-point mean gain in composite reach score may therefore carry injury-risk implications beyond the balance outcome itself. This interpretation is, however, inferential: injury incidence was not measured in the present trial, and no conclusion about an injury-prevention effect can be drawn from these data.

4.2 Physical performance outcomes

The greater improvement in vertical jump height in the Experimental group is consistent with the finding of Dello Iacono, Padulo and Ayalon that core stability training improves lower-limb balance strength and performance in trained athletes,³¹ and with the neuromuscular and athletic performance benefits reported by Prieske et al. following core strength training in elite youth soccer players, particularly under unstable conditions.³² Mechanistically, a stable proximal trunk supplies a more effective base for force transfer to the lower limbs during explosive tasks,¹³ consistent with biomechanical models describing the lumbar spine as a mechanically stabilised system upon which efficient limb force production depends.¹⁰

The change-of-direction gains accord with evidence that trunk neuromuscular control is a determinant of both injury risk and movement efficiency during cutting and pivoting,²³ with systematic review evidence that core stability training can produce meaningful gains in agility and multidirectional performance in soccer players,²⁰ and with the proposal that optimising core stability and strength improves overall athletic performance.²⁴ Biomechanical analyses identifying trunk and hip control, alongside lower-limb strength and technique, as key determinants of change-of-direction ability in elite soccer players²⁹ provide a plausible explanation for why a programme targeting trunk and hip control specifically would influence this outcome.

The sprint finding requires more cautious interpretation, because it diverges from the most directly relevant pooled evidence. A recent meta-analysis focused specifically on core stability training and speed performance in soccer players found no significant pooled effect on 20-metre or 30-metre sprint times,¹⁸ whereas broader team-sport and general athletic literature reports more favourable, though modest, effects on sprint-related outcomes.^{25,26} Two explanations for the significant 0.09 s between-group difference observed here seem plausible. First, the content and progression of the present protocol may differ materially from the more isolated core stability programmes evaluated in prior reviews: the weeks 7–8 functional phase incorporated acceleration–deceleration and football-movement integration drills with an explicit locomotor component, which may have contributed a training stimulus that isolated trunk exercises would not. Second, because sprint mechanics are heavily determined by lower-limb strength, stride characteristics and technique, the core-stability-attributable component of the observed improvement is plausibly smaller than that for balance outcomes, even though it reached statistical significance in this sample. This finding should therefore be regarded as hypothesis-generating rather than as evidence that core stability training reliably improves linear speed.

4.3 Magnitude of effect and practical application

The effect sizes observed here (Cohen's d 2.21–3.19) are appreciably larger than those typically reported for core stability interventions in the wider sports-science literature, where moderate effects are more common for balance and performance outcomes. Several features of the present trial may contribute. Adherence was high ($92.2 \pm 4.7\%$), so the delivered dose closely approximated the prescribed dose. Progression was criterion-based, so participants advanced only once adequate technique and movement control were demonstrated, reducing the dilution of training quality that time-based progression can produce. The concurrent standard football training context may also have provided repeated opportunity for improved core control to transfer into functional, sport-relevant movement. Nonetheless, effect sizes of this magnitude in a single-centre trial with an unblinded intervention should be interpreted conservatively and require replication in larger, multi-centre samples before they are treated as the expected effect of this intervention.

From an applied standpoint, match play requires repeated high-intensity efforts, rapid direction changes and single-leg landings, frequently under progressive fatigue and in an unpredictable environment.^{1,2} Improvements of the magnitude observed may translate into a more secure base for technical execution during match play, although the present study assessed standardised field-based tests rather than in-match performance. The programme was time-efficient — approximately 25–30 minutes, three times weekly — and required minimal equipment, making it feasible for coaches and sports physiotherapists working with college, district and state-level squads to deliver alongside conventional strength and conditioning work. Consistent with integrative neuromuscular training literature,³⁰ such programmes are best positioned as one component of comprehensive athletic development rather than a stand-alone substitute for sprint-specific or strength-specific conditioning, a distinction embodied in the present design, in which core stability training was added to rather than replacing standard football training.

4.4 Strengths and limitations

Strengths of this trial include randomised allocation with concealed assignment, blinded outcome assessment, an active comparator that isolates the incremental effect of the intervention, complete follow-up with no attrition, documented adherence, a fully specified and reproducible exercise protocol, and the concurrent assessment of five complementary balance and performance outcomes within a single design — the specific gap identified in the existing literature.

Several limitations must nonetheless be acknowledged.

- Follow-up was limited to the immediate post-intervention assessment at week 8. Whether the additional gains are retained, and whether they translate into reduced injury incidence or improved match performance across a full competitive season, cannot be determined from these data.
- Participant and trainer blinding was not feasible. Although the outcome assessor was blinded, participant expectation could plausibly have influenced performance on effort-dependent tests such as vertical jump and sprint, and may contribute to the unusually large observed effect sizes.
- Randomisation produced a chance imbalance in sex distribution (28 male / 2 female in the Experimental group versus 22 male / 8 female in the Control group). Neuromuscular parameters have been shown to influence dynamic balance differently in male and female football players,²⁷ and although baseline outcome scores were comparable between groups, this imbalance cannot be excluded as a contributing factor. Stratified randomisation by sex should be used in future trials.
- Recruitment was from a single institutional setting, which limits generalisability to other football populations, playing levels and geographic regions.
- The sample was restricted to players aged 18–26 years competing at college/university, district and state level, so the findings may not generalise to younger, elite/professional or masters-level players.
- Injury incidence, in-match performance and psychological or perceptual outcomes such as confidence and fear of reinjury were not measured and cannot be commented upon.
- The trial was not powered to test for sex-by-group or position-by-group interactions, so differential response by sex or playing position remains unexamined.

4.5 Recommendations for future research

Future trials should recruit larger samples across multiple clubs, academies or institutions; use stratified randomisation by sex or be powered to test sex-based differences in treatment response; extend follow-up beyond the immediate post-intervention assessment and across a full competitive season to establish retention and any association with injury incidence; and, where feasible, employ a sham or attention-control condition to strengthen methodological rigour. Given the equivocal sprint-specific evidence base,¹⁸ head-to-head comparison of different

core stability exercise selections and progressions would help identify which components, if any, are responsible for the sprint gains reported in some studies including this one. Incorporating in-match GPS-derived physical performance data, injury surveillance and player- and coach-reported outcomes would provide a more comprehensive picture of intervention effect, while mechanistic work examining whether benefit is mediated specifically by improvements in trunk neuromuscular control²³ would clarify the pathway linking core stability training to the observed gains. Qualitative investigation of player and coach experience would add insight into acceptability, perceived benefit and barriers to long-term adherence.

5. Conclusion

An eight-week structured, criterion-progressed core stability training programme delivered as an adjunct to standard football training produced significantly greater improvement in static balance, dynamic balance, vertical jump height, 20-metre sprint time and 505 change-of-direction time than standard football training alone in college, district and state-level football players, with large-to-very-large effect sizes across all five outcomes. The consistency of benefit across both balance and performance domains, assessed concurrently in the same cohort, provides empirical support for the proposed kinetic-chain pathway by which improved proximal neuromuscular control transfers to distal athletic performance. The programme is time-efficient and requires minimal equipment, making it a practical addition to existing football conditioning. Because injury incidence was not measured, no conclusion regarding an injury-prevention effect can be drawn, notwithstanding the plausible mechanistic link between improved dynamic balance and reduced lower-extremity injury risk. Replication in larger, multi-centre samples with longer follow-up is required before the magnitude of effect observed here can be considered generalisable.

Declarations

Ethics approval and consent to participate. Ethical approval was granted by the Institutional Ethics Committee of the Institute of Applied Medicines and Research, Ghaziabad, Uttar Pradesh, India [insert approval number and date]. The study was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants prior to enrolment.

Trial registration. [Insert Clinical Trials Registry – India (CTRI) registration number and date of registration, or state that the trial was not prospectively registered.]

Consent for publication. Not applicable; no individually identifiable participant data are reported.

Availability of data and materials. The datasets generated and analysed during the current study are available from the corresponding author on reasonable request.

Competing interests. The authors declare that they have no competing interests.

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Authors' contributions. DKY conceived and designed the study, recruited participants, delivered the intervention, collected and analysed the data, and drafted the manuscript. HS supervised the study, contributed to the design and methodology, critically revised the manuscript for important intellectual content, and provided overall guidance. Both authors read and approved the final manuscript and agree to be accountable for all aspects of the work.

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