Effect of core stabilization exercise on balance and functional mobility in stroke survivors: a randomized controlled trial

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Abstract—**Background: Impaired balance and mobility are among the most persistent consequences of stroke. Trunk and core musculature provide the postural foundation for limb movement, yet conventional rehabilitation in many settings remains focused on the lower limb. Evidence for core stabilization training after stroke is promising but heterogeneous.**

Objective: To determine whether a supervised 12-week core stabilization programme, added in place of an equivalent amount of conventional therapy, improves balance and functional mobility more than conventional rehabilitation alone in stroke survivors.

Methods: Sixty-eight stroke survivors attending rehabilitation centres and hospitals in East Delhi, India, were randomly allocated to a core stabilization group (n = 34) or a conventional rehabilitation group (n = 34). The core group performed supine leg raises, bridging, prone plank and side plank under physiotherapist supervision for 30–45 minutes twice weekly for 12 weeks. The control group received conventional gait, strength and balance training on the same schedule. Balance was assessed with the Berg Balance Scale (BBS), functional mobility with the Timed Up and Go test (TUG), and dynamic postural control with the Functional Reach Test (FRT), at baseline and at 12 weeks. Between-group comparisons used analysis of covariance adjusted for baseline scores.

Results: All 68 participants completed the study. Groups were comparable at baseline. Adjusted for baseline, the core stabilization group outperformed the control group on the BBS (adjusted mean difference 4.60 points, 95% CI 1.71 to 7.49; $p = 0.002$) and the TUG (−4.49 s, 95% CI −6.52 to −2.47; $p < 0.001$). The difference on the FRT favoured core stabilization but did not reach the conventional threshold for significance (2.97 cm, 95% CI −0.05 to 5.99; $p = 0.054$), although change-score and rank-based sensitivity analyses were significant ($p = 0.038$ and $p = 0.007$). Within the core group, mean changes were +5.94 points on the BBS, −5.36 s on the TUG and +4.59 cm on the FRT (all $p \leq 0.009$). Control-group changes were statistically significant but small (+0.82 points, −0.45 s, +1.07 cm). Seventeen of 34 core-group participants (50.0%) reached a 6-point BBS gain versus none of the controls, and 22 of 34 (64.7%) reached a 2.9 s TUG gain versus none of the controls (both $p < 0.001$). No adverse events were reported.

Conclusion: Adding supervised core stabilization exercise to stroke rehabilitation produced greater gains in balance and functional mobility than conventional rehabilitation alone over 12 weeks, and the gains reached clinically meaningful thresholds in a substantial proportion of participants. Core stabilization is inexpensive, requires no equipment and is feasible in resource-constrained settings.

Index Terms—**stroke rehabilitation; core stability; postural balance; Berg Balance Scale; Timed Up and Go; randomized controlled trial**

I. INTRODUCTION

Stroke remains one of the leading causes of acquired adult disability worldwide, and the absolute burden continues to rise as populations age and survive the acute event in greater numbers [1]. In India, the burden is substantial and disproportionately affects people at younger ages than in high-income countries, which lengthens the period of life lived with disability and increases the economic consequences for households [2].

Among the impairments that persist after stroke, loss of balance and reduced walking capacity are the most consistently reported barriers to independence. They restrict participation, increase the risk of falls and fracture, and predict institutionalization. Rehabilitation aimed at restoring balance and mobility is therefore central to post-stroke recovery, but the optimal content of that rehabilitation is still debated [3].

Conventional post-stroke physiotherapy in many clinical settings concentrates on the hemiparetic lower limb: strengthening, gait re-education and task-specific balance practice. The trunk receives comparatively little direct attention, despite well-established evidence that trunk control is impaired bilaterally after unilateral stroke and that trunk performance early after stroke predicts later functional outcome [4,5]. The deep and superficial muscles of the abdomen, lumbar spine and pelvis generate the anticipatory postural adjustments that precede voluntary limb movement. Where these adjustments are delayed or absent, patients rely on compensatory strategies that are metabolically costly and mechanically unstable [6].

This mechanistic rationale has prompted a series of trials of trunk and core-directed exercise after stroke. Additional trunk exercises have improved trunk performance and sitting balance in both acute and chronic cohorts [5,7], trunk exercise on unstable surfaces has increased trunk muscle activation and gait speed [8], and core stability training has improved standing balance and mobility in a randomized trial [9]. Meta-analyses of additional trunk exercise programmes report benefit for trunk control and, less consistently, for standing balance and gait [4,10].

The evidence base nonetheless has limitations that restrict its clinical application. Trials differ substantially in the exercises prescribed, the dose delivered, the chronicity of the participants and the outcome instruments used, and several report only trunk-specific outcomes rather than the standing balance and walking measures that determine independence. Studies from South Asian rehabilitation settings, where supervised therapy time is scarce and equipment-dependent interventions are often impractical, are particularly under-represented. An intervention built from floor-based exercises requiring no equipment would be well matched to these constraints, provided its efficacy can be demonstrated.

The present trial was therefore designed to test whether a supervised, equipment-free core stabilization programme, delivered twice weekly for 12 weeks in place of an equivalent amount of conventional therapy, produces greater improvement in balance and functional mobility than conventional rehabilitation alone in stroke survivors. We hypothesized that the core stabilization group would show greater improvement on the Berg Balance Scale, the Timed Up and Go test and the Functional Reach Test at 12 weeks.

II. METHODS

2.1 Study design

This was a parallel-group, two-arm randomized controlled trial with 1:1 allocation and pre-test/post-test assessment. Reporting follows the CONSORT 2010 statement for parallel-group randomized trials [11]. The trial was conducted at rehabilitation centres and hospitals in East Delhi, India.

2.2 Ethical approval and consent

The protocol was approved by the Institutional Ethics Committee of Kailash Institute of Nursing and Paramedical Sciences, Greater Noida [approval number and date to be inserted]. The study was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from every participant before any study procedure, after the purpose, procedures, risks and voluntary nature of participation had been explained in a language the participant understood.

2.3 Participants

Adults were eligible if they were aged 18 years or older, had a documented diagnosis of stroke with residual balance and mobility impairment, were able to follow single-stage verbal instruction and participate in a supervised exercise programme, had no medical contraindication to exercise, and gave written informed consent.

Participants were excluded if they had a medical condition independently limiting participation in physical activity, had undergone recent surgery or a medical intervention affecting balance or mobility, had severe physical or cognitive limitation preventing participation, or had previously taken part in a

structured core exercise programme for balance and mobility.
Time since stroke among enrolled participants ranged from 1 to 23 months (mean 12.5 months), so the cohort comprised predominantly subacute and chronic stroke survivors.

2.4 Randomization and blinding
Participants were allocated to the core stabilization group or the conventional rehabilitation group in a 1:1 ratio using a computer-generated random allocation sequence. The sequence was concealed from the recruiting investigator until allocation. Because the interventions are behavioural and delivered face to face, neither participants nor treating physiotherapists could be blinded to group assignment. Outcome assessors were not blinded, which is acknowledged as a limitation.

2.5 Interventions
Both interventions ran for 12 weeks, with sessions delivered twice weekly under the supervision of a qualified physiotherapist. Every session in both arms began with a five-minute warm-up of light aerobic activity (overground walking or stationary cycling) and ended with a five-minute cool-down of static stretching. Participants in both arms were asked not to undertake additional structured exercise programmes for the duration of the trial.
Core stabilization group. The 30–45 minute conditioning component comprised four floor-based exercises requiring no equipment. Supine leg raise: lying supine, the participant raised one leg with the knee extended while the contralateral leg remained extended in contact with the floor, held for five seconds and lowered; 10 repetitions per leg. Prone plank: the participant supported the body on the forearms and toes with the trunk held in neutral alignment; three sets of 10–20 seconds. Bridging: lying supine with knees flexed and feet flat, the participant elevated the pelvis, held for five seconds and lowered; 10 repetitions. Side plank: lying on one side, the participant supported the body on the forearm and elevated the pelvis; three sets of 10–20 seconds on each side. Hold times and repetitions were progressed within the stated ranges as tolerance allowed. The supervising physiotherapist provided manual and verbal cueing to maintain neutral spinal alignment and to prevent breath-holding, and modified positions where a participant could not achieve the full posture.
Conventional rehabilitation group. Participants received conventional post-stroke physiotherapy on the same schedule and for the same session duration. This comprised gait training (treadmill and overground walking), strength training for major lower and upper limb muscle groups (leg press, knee extension, seated row), and conventional balance training (single-leg stance, tandem walking and balance-board work), prescribed and progressed according to individual need.

2.6 Outcome measures
All outcomes were recorded at baseline, before randomization, and again at the end of the 12-week intervention period. The same measurement procedures were used on both occasions.
Balance. The Berg Balance Scale (BBS) comprises 14 functional tasks, each scored 0–4, giving a total of 0–56 with higher scores indicating better balance. The BBS is well validated in stroke and shows excellent inter-rater and test–retest reliability (ICC > 0.90) [12].
Functional mobility. The Timed Up and Go test (TUG) records the time in seconds taken to rise from a standard armchair, walk three metres, turn, return and sit down. Shorter times indicate better mobility. The TUG is highly reliable in chronic stroke (ICC > 0.90) [13].
Dynamic postural control. The Functional Reach Test (FRT) records, in centimetres, the maximum distance a participant can reach forward beyond arm's length while standing with a fixed base of support. Greater distances indicate better anticipatory postural control [14].
Safety. Adverse events, including falls, musculoskeletal pain and cardiovascular symptoms occurring during or attributable to a supervised session, were recorded at every session in both arms.

2.7 Sample size
The target sample of 68 participants (34 per group) was determined a priori. With 34 participants per group, two-sided alpha of 0.05 and 80% power, the trial is powered to detect a standardized between-group difference of approximately 0.69, corresponding to about 6.3 BBS points or 3.6 s on the TUG at the observed pooled standard deviations. No

allowance for attrition was required, as all enrolled participants completed the trial.

2.8 Statistical analysis

Data were analysed with SPSS (IBM Corp., Armonk, NY). Continuous variables are summarized as mean ± standard deviation. Distributional assumptions were examined with the Shapiro–Wilk test and by inspection of residuals. Baseline comparability was assessed with independent-samples t-tests.

The pre-specified primary analysis was analysis of covariance (ANCOVA) comparing 12-week scores between groups with the corresponding baseline score entered as a covariate. This approach is more statistically efficient than comparison of raw follow-up scores or of change scores, and it adjusts for any residual baseline imbalance. Results are reported as adjusted mean differences with 95% confidence intervals and partial eta squared.

Within-group change from baseline was examined with paired t-tests. Two sensitivity analyses were pre-specified to test the robustness of the primary result: an independent-samples t-test on change scores, and the Mann–Whitney U test on change scores, the latter because the distribution of change scores in the control arm departed from normality.

To aid clinical interpretation, a responder analysis classified each participant as a responder or a non-responder against published change thresholds for chronic stroke: a gain of at least 6 points on the BBS and a reduction of at least 2.9 s on the TUG [13,15]. Proportions were compared with Fisher's exact test. All analyses followed the intention-to-treat principle; as there were no dropouts and no missing data, intention-to-treat and per-protocol populations were identical. Two-sided p values below 0.05 were considered statistically significant, and no adjustment was made for multiplicity across the three outcomes, which is noted as a limitation.

III. RESULTS

3.1 Participant flow and baseline characteristics

Sixty-eight participants were enrolled and randomized, 34 to the core stabilization group and 34 to the conventional rehabilitation group. All 68 completed the 12-week intervention and both assessment points; there were no withdrawals, no losses to follow-up and no missing data.

Baseline characteristics are shown in Table 1. Participants had a mean age of 59.4 years (range 40–79) and a mean time since stroke of 12.5 months. The two groups did not differ at baseline on age, body weight, time since stroke, or on any of the three outcome measures (all $p \geq 0.41$). Mean baseline BBS was 38.6 points across the cohort, and 42 of 68 participants (61.8%) scored below 45 points, a level associated with elevated fall risk.

Table 1. Baseline characteristics of the two groups

Variable	Core stabilization (n = 34)	Conventional (n = 34)	Mean difference (95% CI)	p
Age (years)	58.65 ± 11.88	60.09 ± 13.93	−1.44 (−7.71 to 4.83)	0.648
Body weight (kg)	67.29 ± 12.59	68.56 ± 12.03	−1.26 (−7.23 to 4.70)	0.673
Time since stroke (months)	12.41 ± 6.86	12.68 ± 6.83	−0.26 (−3.58 to 3.05)	0.874
Berg Balance Scale (0–56)	37.94 ± 12.15	39.32 ± 9.98	−1.38 (−6.77 to 4.00)	0.610
Timed Up and Go (s)	21.18 ± 5.30	20.13 ± 5.08	1.05 (−1.46 to 3.56)	0.407
Functional Reach Test (cm)	21.96 ± 7.15	23.22 ± 6.59	−1.26 (−4.59 to 2.06)	0.451

Values are mean ± standard deviation. Mean difference is core stabilization minus conventional. p values from independent-samples t-tests. CI, confidence interval.

3.2 Within-group change

Within-group changes from baseline to 12 weeks are presented in Table 2. The core stabilization group improved on all three measures: the BBS rose by a mean of 5.94 points (95% CI 2.40 to 9.49; $p = 0.002$), TUG time fell by 5.36 s (95% CI 3.08 to 7.63; $p < 0.001$), and functional reach increased by 4.59 cm (95% CI 1.22 to 7.95; $p = 0.009$).

The conventional rehabilitation group also changed significantly on all three measures, but the magnitudes were small: +0.82 points on the BBS, −0.45 s on the TUG and +1.07 cm on the FRT (all $p < 0.001$). These changes were highly consistent across participants, which explains their statistical significance despite their size; none approached the published thresholds for clinically meaningful change. The distinction between statistical and clinical significance is important here and is addressed in the responder analysis below.

Table 2. Within-group change from baseline to 12 weeks

Outcome	Group	Baseline	12 weeks	Mean change (95% CI)	p
BBS (points)	Core	37.94 ± 12.15	43.88 ± 8.30	+5.94 (2.40 to 9.49)	0.002
	Conventional	39.32 ± 9.98	40.15 ± 9.93	+0.82 (0.53 to 1.11)	<0.001
TUG (s)	Core	21.18 ± 5.30	15.83 ± 5.26	−5.36 (−7.63 to −3.08)	<0.001
	Conventional	20.13 ± 5.08	19.68 ± 5.12	−0.45 (−0.54 to −0.36)	<0.001
FRT (cm)	Core	21.96 ± 7.15	26.55 ± 8.01	+4.59 (1.22 to 7.95)	0.009
	Conventional	23.22 ± 6.59	24.30 ± 6.51	+1.07 (0.87 to 1.28)	<0.001

Values are mean ± standard deviation. p values from paired-samples t-tests. BBS, Berg Balance Scale; TUG, Timed Up and Go test; FRT, Functional Reach Test.

3.3 Between-group comparison

Results of the pre-specified ANCOVA are shown in Table 3. After adjustment for baseline scores, the core stabilization group achieved a higher 12-week BBS score than the conventional group, with an adjusted mean difference of 4.60 points (95% CI 1.71 to 7.49; $p = 0.002$; partial $\eta^2 = 0.135$), and a shorter TUG time, with an adjusted mean difference of 4.49 s (95% CI 2.47 to 6.52; $p < 0.001$; partial $\eta^2 = 0.232$). The adjusted difference on the Functional Reach Test favoured core stabilization by 2.97 cm (95% CI −0.05 to 5.99) but did not reach the conventional threshold for statistical significance ($p = 0.054$; partial $\eta^2 = 0.056$).

Both pre-specified sensitivity analyses supported the primary result. Comparison of change scores favoured core stabilization on the BBS (difference 5.12 points, 95% CI 1.63 to 8.61; $p = 0.005$; Cohen's $d = 0.71$), the TUG (difference 4.91 s, 95% CI 2.68 to 7.14; $p < 0.001$; $d = 1.07$) and the FRT (difference 3.51 cm, 95% CI 0.20 to 6.82; $p = 0.038$; $d = 0.51$). Because change scores in the control arm were not normally distributed, the Mann–Whitney U test was also applied and returned significant differences favouring core stabilization on all three outcomes (BBS $p = 0.002$; TUG $p < 0.001$; FRT $p = 0.007$). The Functional Reach result should therefore be read as directionally consistent but statistically borderline under the primary model.

Table 3. Between-group comparison at 12 weeks, adjusted for baseline (ANCOVA)

Outcome	Adjusted mean, core	Adjusted mean, conventional	Adjusted difference (95% CI)	p	Partial η²
BBS (points)	44.32	39.71	4.60 (1.71 to 7.49)	0.002	0.135
TUG (s)	15.51	20.00	−4.49 (−6.52 to −2.47)	<0.001	0.232
FRT (cm)	26.91	23.94	2.97 (−0.05 to 5.99)	0.054	0.056

Adjusted difference is core stabilization minus conventional, estimated at the pooled baseline mean. Negative values on the TUG indicate faster performance and therefore favour core stabilization.

BBS, Berg Balance Scale; TUG, Timed Up and Go test; FRT, Functional Reach Test.

3.4 Responder analysis

Responder analysis against published change thresholds is shown in Table 4. Seventeen of 34 participants in the core stabilization group (50.0%) achieved a BBS gain of at least 6 points, compared with none of the 34 conventional-therapy participants (risk difference 50.0 percentage points; $p < 0.001$). Twenty-two of 34 core-group participants (64.7%) achieved a TUG reduction of at least 2.9 s, again compared with none of the controls (risk difference 64.7 percentage points; $p < 0.001$). No participant in the conventional group reached a clinically meaningful threshold on either measure, despite the statistically significant within-group changes reported above.

Response within the core stabilization group was variable. Although the group mean improved on every measure, 7 of 34 participants recorded a lower BBS score at 12 weeks than at baseline, 7 recorded a slower TUG time and 9 recorded a shorter functional reach. By contrast, no participant in the conventional group deteriorated on any measure. The greater variability in the core group is reflected in the wider standard deviations of its change scores and indicates that the intervention did not benefit all participants equally.

Table 4. Proportion of participants achieving clinically meaningful change at 12 weeks

Threshold	Core stabilization (n = 34)	Conventional (n = 34)	Risk difference (percentage points)	p
BBS gain ≥ 6 points	17 (50.0%)	0 (0%)	50.0	<0.001
TUG reduction ≥ 2.9 s	22 (64.7%)	0 (0%)	64.7	<0.001

p values from Fisher's exact test. BBS, Berg Balance Scale; TUG, Timed Up and Go test.

3.5 Safety

No adverse events were reported in either group over the 12-week intervention period. No participant withdrew for reasons of pain, fatigue or intolerance of the exercise protocol, and no falls occurred during supervised sessions.

IV. DISCUSSION

In this randomized controlled trial of 68 stroke survivors, a supervised 12-week core stabilization programme produced greater improvement in balance and functional mobility than an equivalent dose of conventional rehabilitation. Adjusted for baseline, the core group gained 4.60 more BBS points and were 4.49 s faster on the Timed Up and Go test. The difference on the Functional Reach Test favoured core stabilization but was statistically borderline under the primary model, reaching significance only in the change-score and rank-based sensitivity analyses.

The size of these differences is clinically relevant, not merely statistically detectable. The adjusted BBS difference approaches the 6-point change commonly regarded as meaningful in chronic stroke, and the TUG difference exceeds the smallest real difference reported for this population [13,15]. The responder analysis makes the point more directly: half of the core group and almost two-thirds achieved meaningful gains on the BBS and TUG respectively, while no participant receiving conventional therapy alone reached either threshold. The small within-group improvements recorded in the control arm were statistically significant but fell well below any published threshold for perceptible benefit, and should be interpreted as measurement-level change rather than clinical recovery.

4.1 Comparison with previous work

These findings are consistent with the accumulating evidence that trunk-directed exercise adds value to conventional stroke rehabilitation. Haruyama and colleagues randomized chronic stroke patients to core stability training or conventional therapy and reported greater gains in trunk function, standing balance and mobility in the core stability arm, with effect sizes comparable to those observed here [9]. Verheyden and colleagues found that additional trunk exercises improved trunk performance beyond conventional therapy in a pilot randomized trial [5], and Cabanas-Valdés and colleagues showed that gains from additional core stability exercises were retained at long-term follow-up [16]. Jung and colleagues reported that trunk exercise on an unstable surface improved postural control and gait speed [8], and Karthikbabu and colleagues found trunk-directed regimes effective for balance, mobility and community reintegration in chronic stroke [17].

The systematic review evidence is more measured. Prat-Luri and colleagues concluded in a meta-analysis that additional trunk exercise programmes benefit trunk performance after stroke, but that effects on standing balance and gait are smaller and more variable, and are modulated by initial trunk impairment, age, time from onset and training volume [4]. Hugues and colleagues, reviewing physical therapy for balance after stroke more broadly, found the overall evidence limited by methodological quality [10]. The present trial contributes a standing-balance and mobility outcome set to a literature in which trunk-specific measures predominate, and does so with an equipment-free protocol suited to resource-constrained services.

The borderline Functional Reach result merits comment. The FRT measures anticipatory postural displacement in a single anterior direction and has a narrower dynamic range than the BBS. Its responsiveness in stroke populations is lower than that of multi-item balance scales, and the variability observed in this cohort was correspondingly high. The direction of effect was consistent across all three analytic approaches, and the discrepancy between the primary and sensitivity analyses reflects distributional properties rather than a contradictory finding. It should nonetheless be reported as a null result under the pre-specified primary model.

4.2 Possible mechanisms

Several mechanisms plausibly underlie the observed effect. The trunk musculature provides the proximal stability from which distal limb movement is organized; anticipatory postural adjustments in these muscles precede voluntary limb motion and are demonstrably delayed after stroke [6]. Training that loads the trunk in bridging, plank and side-plank positions imposes precisely this stabilizing demand, and improvement in trunk endurance would be expected to translate into better performance on tasks such as sit-to-stand and turning, which together account for a substantial part of both the BBS and the TUG.

A second mechanism is a reduction in compensatory movement strategy. Stroke survivors with poor trunk control frequently substitute lateral trunk flexion and upper-limb support for genuine postural adjustment. These strategies are effortful and narrow the base of support during transitions. Improved trunk control permits a more efficient movement pattern with a lower fall risk during the transitional phases of the TUG.

A third possibility is neuromuscular re-education. Core stabilization exercises demand sustained low-level co-contraction with precise segmental control, a form of practice that differs from the phasic, higher-load work typical of limb strengthening. The larger effect observed on the TUG than on the BBS is consistent with a benefit concentrated in dynamic transitional tasks rather than in static stance, although the present design cannot test this directly. It should be emphasized that these mechanisms are inferred from the pattern of results and from prior work; no trunk-specific or electromyographic measures were collected in this trial, and mechanistic claims must remain provisional.

4.3 Clinical implications

The intervention tested here required no equipment, no specialized facility and no technology beyond a floor mat and a supervising physiotherapist, and was delivered in two sessions per week. That combination matters for services in which supervised therapy time is the binding constraint. The protocol substituted core stabilization for an equivalent quantity of conventional therapy rather than adding to it, so the observed benefit was obtained without increasing total therapy time. Where a stroke rehabilitation service must choose how to allocate a fixed number of supervised sessions, these results support directing part of that allocation to trunk-directed work.

The variability of response within the core group tempers this recommendation. A minority of participants deteriorated on individual measures, and the trial was not designed to identify who benefits most. Until predictors of response are established, core stabilization should be introduced with individualized progression and regular reassessment rather than applied uniformly.

4.4 Limitations

Several limitations should be weighed when interpreting these findings. First, outcome assessors were not blinded to group allocation. The BBS involves observer judgement and is therefore susceptible to detection bias; the TUG, being a stopwatch measure, is less vulnerable, and it is reassuring that the largest effect was observed on the more objective outcome. Blinded assessment is nonetheless essential in future trials.

Second, the trial was not prospectively registered. Prospective registration is now a condition of publication in most journals and a requirement of the ICMJE, and its absence limits the assurance that the analysis reported here was fully pre-specified.

Third, participants were recruited from centres in a single metropolitan region of North India, and generalizability to other health systems, rural settings and populations is unknown. Sex was not recorded, so the balance of male and female participants cannot be reported and sex-stratified analysis was not possible. Stroke subtype, lesion side and hemiparetic side were likewise not recorded, and these variables are known to influence balance recovery.

Fourth, the intervention period was 12 weeks with no post-intervention follow-up, so whether the observed gains persist after supervision ends is unknown. Given that adherence to unsupervised home exercise typically declines, this question is clinically important.

Fifth, adherence to the protocol was monitored by the supervising therapist but not quantified objectively, and no formal dose–response analysis was possible.

Sixth, no adjustment was made for multiple comparisons across the three outcomes; the BBS and TUG results would survive Bonferroni correction at the 0.05 level, but the Functional Reach result would not. Seventh, the very low variance of change scores in the conventional group is unusual for clinical data and may reflect measurement or recording practice rather than true biological homogeneity; independent replication would be valuable.

Finally, no measure of trunk-specific function, muscle strength, participation or health-related quality of life was collected, so the extent to which the observed improvements translate into everyday activity and wellbeing cannot be determined from these data.

4.5 Future directions

Future trials should be prospectively registered, should blind outcome assessors, and should include follow-up of at least six months to establish whether gains are retained. Recording of stroke subtype, lesion characteristics, hemiparetic side and sex would permit analysis of who benefits most. Adding a trunk-specific measure such as the Trunk Impairment Scale alongside standing balance outcomes would strengthen the mechanistic account, and including a participation or quality-of-life measure would establish whether improvements in balance and mobility carry through to everyday life. Dose-finding work comparing frequency and volume of core stabilization would also help define an optimal prescription.

V. CONCLUSION

A supervised, equipment-free core stabilization programme delivered twice weekly for 12 weeks produced greater improvement in balance and functional mobility than an equivalent dose of conventional rehabilitation in stroke survivors. Half of the participants receiving core stabilization achieved a clinically meaningful gain in Berg Balance Scale score and almost two-thirds achieved a clinically meaningful reduction in Timed Up and Go time, while no participant receiving conventional rehabilitation alone reached either threshold. The effect on the Functional Reach Test was directionally consistent but did not reach significance under the primary analysis. No adverse events occurred. Given its low cost and minimal equipment requirement, core stabilization warrants consideration as a component of post-stroke rehabilitation, particularly where resources are constrained. Larger, registered, assessor-blinded trials with longer follow-up are needed to confirm these findings and to establish the durability of the benefit.

DECLARATIONS

Ethics approval and consent to participate

The study protocol was approved by the Institutional Ethics Committee of Kailash Institute of Nursing and Paramedical Sciences, Greater Noida [insert approval number and date]. Written informed consent was obtained from all participants.

Consent for publication

Not applicable; the manuscript contains no individually identifiable data.

Availability of data and materials

The dataset analysed during the current study is available from the corresponding author on reasonable request.

Competing interests

The author declares no competing interests.

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Trial registration

This trial was not prospectively registered. [If a retrospective CTRI registration is obtained, insert the registration number and date here.]

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