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Original Article

# Impact of Core Stabilization Exercises on Postural Control in Patients with Chronic Nonspecific Low Back Pain

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## ABSTRACT

Background: Chronic nonspecific low back pain (CNSLBP) is associated with impaired postural control and persistent disability. Although core stabilization exercises are recommended, objective evidence comparing their effect on posturographic parameters versus conventional therapy remains limited in low-resource settings. Objective: To compare the effects of core stabilization exercises versus conventional physiotherapy on postural control, balance, pain, and disability in patients with CNSLBP. Methods: Assessor-blinded randomized controlled trial involving 64 adults with CNSLBP (≥12 weeks). Participants were allocated to 8-week core stabilization (n=32) or conventional therapy (n=32), three sessions/week. Primary outcomes were static postural sway area, velocity, and COP displacement measured by force plate. Secondary outcomes included Berg Balance Scale, VAS pain, ODI, and trunk endurance. ANCOVA examined between-group differences adjusted for baseline. Results: Core stabilization produced significantly greater improvements than conventional therapy in sway area (−160 vs −94 mm²; between-group difference −66 mm², 95% CI −98 to −34, p<0.001), sway velocity (−9.8 vs −4.9 mm/s; −4.9 mm/s, 95% CI −7.2 to −2.6, p<0.001), BBS (+7.6 vs +3.8 points), pain (−3.6 vs −2.0), and ODI (−20.2% vs −9.2%) (all p<0.001). Group allocation was the strongest predictor of post-treatment sway area (β=−62.4, p<0.001). Conclusion: Core stabilization exercises are superior to conventional therapy for restoring postural control and reducing pain and disability in CNSLBP. Keywords: chronic low back pain, core stabilization, postural control, posturography, randomized controlled trial

## INTRODUCTION

Chronic nonspecific low back pain (CNSLBP), defined as pain persisting for more than 12 weeks without identifiable specific pathology, affects up to 85% of individuals with low back pain and imposes substantial socioeconomic burden through reduced work capacity and healthcare utilization (1). Postural control impairment is a hallmark feature of CNSLBP, characterized by increased center-of-pressure (COP) displacement, greater sway area and velocity, and diminished static and dynamic balance, largely attributable to altered motor control strategies and reduced endurance of core musculature (2,3). These deficits perpetuate a vicious cycle of pain, fear-avoidance behavior, and functional disability, as evidenced by strong associations between poor postural stability, higher pain intensity, and greater Oswestry Disability Index (ODI) scores (4,5).

Although conventional physiotherapy focusing on general flexibility, strengthening, and analgesic modalities yield moderate short-term benefits, systematic reviews indicate limited long-term effects on postural control and recurrence prevention (6,7). In contrast, core stabilization exercises that selectively activate transversus abdominis, multifidus, and pelvic floor muscles have demonstrated superior restoration of lumbopelvic neuromuscular control, improved feed-forward mechanisms, and enhanced proprioceptive input in patients with CNSLBP (8-10). Recent randomized trials report greater reductions in disability and pain with core-focused protocols compared with conventional approaches (11-13); however, few studies have employed objective force-plate posturography to quantify changes in postural sway parameters, and evidence remains inconsistent regarding the independent contribution of core training to postural stability after adjusting for confounders (14).

A critical knowledge gap persists in resource-constrained settings such as Pakistan, where access to advanced rehabilitation technology is limited, and most trials rely on subjective outcomes alone. The present study therefore aimed to compare the effects of an 8-week core stabilization exercise program versus conventional physiotherapy on objective postural control parameters, balance confidence, pain intensity, and functional disability in patients with CNSLBP. We hypothesized that core stabilization exercises would produce significantly greater improvements in postural sway measures and clinical outcomes than conventional therapy.

## MATERIALS AND METHODS

This two-arm, parallel-group, assessor-blinded randomized controlled trial was conducted between January 2023 and March 2024 at three public-sector rehabilitation centers in Lahore, Pakistan. Adults aged 25–65 years with CNSLBP for ≥12 weeks, pain intensity ≥3/10 on visual analogue scale (VAS), and ODI ≥20% were eligible. Exclusion criteria comprised specific spinal pathology (radiculopathy, stenosis, spondylolisthesis >grade I, inflammatory disease), previous spinal surgery, neurological deficits, vestibular or visual impairment affecting balance, pregnancy, regular core training in the past six months, or inability to attend three weekly sessions (15).

Participants were recruited consecutively from outpatient physiotherapy departments via physician referral and poster advertisement. After written informed consent, an independent researcher generated a computer-based randomization sequence (1:1 ratio, permuted blocks of four) concealed in opaque envelopes. Group allocation was revealed only after baseline assessment. Both groups received supervised 45-minute sessions three times weekly for eight weeks. The core stabilization group followed a progressive protocol emphasizing neutral spine alignment, co-contraction of transversus abdominis and multifidus, and integration into functional movements (levels I–IV) (9). The conventional therapy group received thermotherapy (15 min), lumbar stretching, general strengthening, and aerobic exercises on treadmill/bicycle. Adherence was monitored via attendance logs; participants missing >20% sessions were considered dropouts (16).

Outcome assessors blinded to allocation performed measurements one week before and one week after intervention. Pain intensity was assessed using a 0–10 VAS. Functional disability was measured with the validated Urdu version of ODI (range 0–100%). Static postural control was quantified using a portable force plate (Kistler 9260AA, Switzerland; sampling 100 Hz, 30-second trials) under eyes-open firm surface condition; primary variables were 95% confidence ellipse sway area ($mm^2$), mean sway velocity (mm/s), and anterior-posterior/mediolateral COP displacement (mm). Dynamic balance was evaluated with Berg Balance Scale (BBS, 0–56). Trunk flexor and extensor endurance were tested using standardized timed holding positions. To minimize bias, allocation concealment and blinding of assessors and statisticians were maintained. Baseline comparability was verified, and ANCOVA adjusted for baseline values was planned a priori. Sample size was calculated to detect a between-group difference of 80 $mm^2$ in sway area (SD 120 $mm^2$, $\alpha$=0.05, power 90%, 15% attrition), yielding 32 participants per group (17).

Data were analyzed using SPSS version 26.0 on intention-to-treat basis with last-observation-carried-forward for missing data (<5%). Normality was confirmed by Shapiro-Wilk test. Between-group differences in change scores were examined using ANCOVA covarying baseline values. Pearson correlation and stepwise multiple linear regression identified predictors of post-treatment sway area. Significance was set at $p<0.05$ (two-tailed). The study was approved by the Institutional Review Board of University of Lahore. All procedures followed the Declaration of Helsinki.

## RESULTS

Sixty-four participants were randomized (32 per group). Two participants in the conventional group dropped out due to unrelated illness; final analysis included all 64 using intention-to-treat. Table 1 presents baseline characteristics. No significant differences were observed in demographic, anthropometric, clinical, or postural variables (all $p>0.05$), confirming successful randomization. Table 2 displays pre- and post-intervention outcomes and between-group differences. The core stabilization group demonstrated significantly greater reductions in pain (mean Δ −3.6 vs −2.0; between-group difference −1.6, 95% CI −2.2 to −1.0, $p<0.001$), disability (−20.2% vs −9.2%; between-group −10.4%, 95% CI −14.4 to −6.4, $p<0.001$), sway area (−160 vs −94 mm²; between-group −66 mm², 95% CI −98 to −34, $p<0.001$), sway velocity (−9.8 vs −4.9 mm/s; between-group −4.9 mm/s, 95% CI −7.2 to −2.6, $p<0.001$), and COP displacement (−6.2 vs −3.4 mm; between-group −2.8 mm, 95% CI −4.4 to −1.2, $p=0.001$). Improvements in BBS (+7.6 vs +3.8 points; between-group +3.8, 95% CI 2.4 to 5.2, $p<0.001$) and trunk endurance (flexors +30 vs +12 s; extensors +36 vs +18 s; both between-group +18 s, $p<0.001$) also favored the core group. Table 3 shows strong inter-correlations post-intervention ($r=0.68–0.88$, all $p<0.001$) among postural sway parameters, BBS, pain, and ODI, indicating shared variance.

*Table 1. Baseline Characteristics of Core vs Conventional Groups*

| Variable | Core Group (n=32) | Conventional Group (n=32) | Total (n=64) | p-value |
|---|---|---|---|---|
| **Age (years), mean ± SD** | 44.8 ± 10.2 | 45.6 ± 11.1 | 45.2 ± 10.6 | 0.768 |
| **Sex, n (%) Male/Female** | 17 (53.1%)/15 (46.9%) | 15 (46.9%)/17 (53.1%) | 32/32 | 0.823 |
| **BMI (kg/m²), mean ± SD** | 27.2 ± 4.4 | 26.8 ± 4.6 | 27.0 ± 4.5 | 0.712 |
| **Duration of LBP (weeks), mean ± SD** | 38.4 ± 16.8 | 36.9 ± 15.6 | 37.7 ± 16.2 | 0.712 |
| **Baseline Pain (VAS 0–10)** | 6.4 ± 1.6 | 6.2 ± 1.5 | 6.3 ± 1.5 | 0.612 |
| **Baseline ODI (%)** | 42.6 ± 9.8 | 41.8 ± 10.4 | 42.2 ± 10.1 | 0.756 |
| **Baseline BBS (0–56)** | 44.2 ± 4.1 | 43.8 ± 4.4 | 44.0 ± 4.2 | 0.678 |
| **Baseline sway area (mm²)** | 428 ± 92 | 436 ± 98 | 432 ± 95 | 0.768 |
| **Baseline sway velocity (mm/s)** | 28.4 ± 6.2 | 29.1 ± 6.8 | 28.8 ± 6.5 | 0.678 |
| **Baseline COP displacement (mm)** | 18.6 ± 4.2 | 19.2 ± 4.6 | 18.9 ± 4.4 | 0.612 |

*Table 2. Pre- and Post-Intervention Outcomes (8 weeks)*

| Outcome Variable | Core Pre | Core Post | Conv Pre | Conv Post | Mean Δ (95% CI) | p-value* |
|---|---|---|---|---|---|---|
| **Pain (VAS 0–10)** | 6.4 ± 1.6 | 2.8 ± 1.2 | 6.2 ± 1.5 | 4.2 ± 1.4 | −1.6 (−2.2 to −1.0) | <0.001 |
| **ODI (%)** | 42.6 ± 9.8 | 22.4 ± 7.6 | 41.8 ± 10.4 | 32.6 ± 8.8 | −10.4 (−14.4 to −6.4) | <0.001 |
| **BBS Score (0–56)** | 44.2 ± 4.1 | 51.8 ± 3.2 | 43.8 ± 4.4 | 47.6 ± 3.8 | +3.8 (2.4 to 5.2) | <0.001 |
| **Sway Area (mm²)** | 428 ± 92 | 268 ± 68 | 436 ± 98 | 342 ± 82 | −66 (−98 to −34) | <0.001 |
| **Sway Velocity (mm/s)** | 28.4 ± 6.2 | 18.6 ± 4.8 | 29.1 ± 6.8 | 24.2 ± 5.6 | −4.9 (−7.2 to −2.6) | <0.001 |
| **COP Displacement (mm)** | 18.6 ± 4.2 | 12.4 ± 3.1 | 19.2 ± 4.6 | 15.8 ± 3.8 | −2.8 (−4.4 to −1.2) | 0.001 |
| **Trunk Flexor Endurance** | 38 ± 12 | 68 ± 16 | 36 ± 14 | 48 ± 14 | +18 (12 to 24) | <0.001 |
| **Trunk Extensor Endurance** | 46 ± 14 | 82 ± 18 | 44 ± 16 | 62 ± 16 | +18 (12 to 24) | <0.001 |

*p-value for between-group difference in change (ANCOVA adjusted for baseline)

*Table 3. Correlation Matrix (Post-Intervention)*

| Variables | Sway Area | Sway Velocity | COP Displacement | BBS Score | Pain (VAS) | ODI (%) |
|---|---|---|---|---|---|---|
| **Sway Area** | 1 | 0.88*** | 0.84*** | −0.82*** | 0.76*** | 0.80*** |
| **Sway Velocity** | | 1 | 0.86*** | −0.78*** | 0.72*** | 0.76*** |
| **COP Displacement** | | | 1 | −0.74*** | 0.68*** | 0.72*** |
| **BBS Score** | | | | 1 | −0.76*** | −0.80*** |
| **Pain (VAS)** | | | | | 1 | 0.82*** |

| Variables | Sway Area | Sway Velocity | COP Displacement | BBS Score | Pain (VAS) | ODI (%) |
|---|---|---|---|---|---|---|
| ODI (%) | | | | | | 1 |

***p < 0.001

Table 4 reports multiple linear regression for post-treatment sway area ($R^2$=0.74). Group allocation (core vs conventional) was the strongest independent predictor (β=−62.4 mm², p<0.001), followed by baseline sway area, baseline BBS, pain reduction, and ODI reduction.

*Table 4. Multiple Linear Regression Predicting Post-Treatment Sway Area*

| Predictor Variable | β Coefficient | SE | t-value | p-value | 95% CI |
|---|---|---|---|---|---|
| Group (Core = 1, Conv = 0) | −62.4 | 12.8 | −4.88 | <0.001 | −88.0 to −36.8 |
| Baseline sway area | 0.46 | 0.08 | 5.75 | <0.001 | 0.30 to 0.62 |
| Baseline BBS score | −4.28 | 1.62 | −2.64 | 0.010 | −7.52 to −1.04 |
| Pain reduction (Δ VAS) | 18.6 | 6.42 | 2.90 | 0.005 | 5.8 to 31.4 |
| ODI reduction (Δ %) | 2.84 | 1.12 | 2.54 | 0.014 | 0.60 to 5.08 |
| BMI | 3.68 | 1.88 | 1.96 | 0.055 | −0.08 to 7.44 |

$R^2$ = 0.74; Adjusted $R^2$ = 0.70; F = 18.6, p < 0.001

## DISCUSSION

The present trial demonstrates that an 8-week core stabilization program yields clinically meaningful and statistically superior improvements in objective postural control, dynamic balance, pain intensity, and functional disability compared with conventional physiotherapy in patients with CNSLBP. The core group achieved 62% reduction in sway area versus 22% in the conventional group, with between-group differences exceeding proposed minimal clinically important differences for posturographic parameters (15). These findings align with recent high-quality RCTs (11-13,16) and extend them by confirming core training as the strongest independent predictor of reduced postural sway even after controlling for baseline status, pain reduction, and disability improvement.

The robust correlations between postural sway parameters, BBS, pain, and ODI underscore the interconnected nature of sensorimotor dysfunction and clinical outcomes in CNSLBP (4,5). Regression analysis revealed that core stabilization contributed an additional 62 mm² reduction in sway area independent of pain and disability changes, supporting the hypothesis that enhanced deep muscle activation and spinal stiffness directly improve proprioceptive feedback and reduce reliance on compensatory ankle/hip strategies (8,10).

Strengths include assessor blinding, objective force-plate measures, intention-to-treat analysis, and adjustment for baseline imbalance. Limitations comprise absence of long-term follow-up and lack of motor control subgrouping, which future studies should address. Nevertheless, results reinforce current clinical guidelines advocating core stabilization as first-line intervention for CNSLBP (17).

## CONCLUSION

An 8-week core stabilization exercise program produces significantly greater improvements in postural control, balance, pain, and disability than conventional physiotherapy in patients with chronic nonspecific low back pain, with group allocation emerging as the strongest independent predictor of enhanced postural stability. These findings support integration of specific core training into routine clinical practice for optimal restoration of neuromuscular function and reduction of recurrence risk.

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