Effectiveness of Core Stabilization Exercises in Lower Back Pain Rehabilitation

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ABSTRACT— Core stabilization exercises (CSE) are widely prescribed in rehabilitation programs for individuals with chronic and recurrent lower back pain (LBP), aiming to enhance neuromuscular control, spinal stability, and functional performance. This prospective randomized controlled trial evaluated the effectiveness of a six-week CSE protocol compared to general exercise (GE) in 100 adults with non-specific LBP. Participants were randomly assigned to CSE (n = 50) or GE (n = 50) groups and underwent supervised sessions three times per week. Primary outcomes included pain intensity (Visual Analog Scale), disability (Oswestry Disability Index), and core muscle endurance (plank and side-bridge hold times), assessed at baseline, post-intervention, and three-month follow-up. Secondary outcomes comprised lumbar kinematics during functional tasks and patient satisfaction. The CSE group demonstrated significantly greater reductions in pain (mean ΔVAS = –3.2 vs. –1.8; p < 0.001) and disability (mean ΔODI = –15.4% vs. –8.7%; p < 0.001) and superior improvements in core endurance (plank +42 s vs. +18 s; side-bridge +28 s vs. +12 s; both p < 0.001). Kinematic analysis revealed enhanced lumbar control in the CSE cohort during bending and lifting tasks (p < 0.01). Benefits were maintained at follow-up. These findings support CSE as a more effective intervention than general exercise for reducing pain, improving function, and augmenting core stability in LBP rehabilitation.

INTRODUCTION

Lower back pain (LBP) affects up to 80% of adults at some point in their lives, representing a leading cause of disability worldwide and imposing substantial personal and societal burdens. Non-specific LBP, characterized by pain without a clear pathoanatomical cause, accounts for the majority of cases and often becomes chronic or recurrent, challenging clinicians to identify effective long-term management strategies. While general exercise programs, including aerobic conditioning and flexibility training, can alleviate symptoms, persistent deficits in core muscle function and motor control are frequently implicated in recurrence. Core stabilization exercises (CSE) target deep trunk muscles—such as transversus abdominis, multifidus, and pelvic floor—aiming to restore optimal segmental stability, reduce aberrant spinal motion, and enhance load distribution during dynamic tasks.

Neuromuscular dysfunction in LBP manifests as delayed activation timing, reduced endurance, and altered recruitment patterns of stabilizing musculature, perpetuating pain cycles and functional limitations. The theoretical framework underpinning CSE posits that training these deep stabilizers improves anticipatory postural adjustments, synergistic

muscle coordination, and proprioceptive acuity. Early intervention with CSE may therefore interrupt maladaptive movement patterns and prevent secondary impairments such as ligamentous strain or facet joint overload.

Figure 1: Effectiveness of Core Stabilization Exercises

Despite growing adoption of CSE in clinical practice, evidence regarding its superiority over general exercise (GE) remains mixed. Several meta-analyses suggest moderate benefits of CSE in reducing pain and disability, yet methodological heterogeneity—varying protocols, durations, and outcome measures—complicates definitive conclusions. Moreover, questions persist about the durability of effects beyond supervised intervention periods and the translation of laboratory-based measures of core function to real-world tasks.

This study aims to address these gaps by conducting a rigorously designed randomized controlled trial comparing a structured six-week CSE program to a matched GE regimen, with outcomes assessed immediately post-intervention and at three-month follow-up. We hypothesize that CSE will yield greater improvements in pain, disability, core muscle endurance, and functional lumbar control than GE, and that these gains will be sustained over time.

LITERATURE REVIEW

The evolution of core stabilization in LBP rehabilitation traces back to Panjabi's seminal work on spinal stability,

which delineated the passive (bony and ligamentous), active (muscular), and neural control subsystems. Panjabi (1992) proposed that deficits in any subsystem could compromise overall stability, predisposing individuals to pain and injury. This model catalyzed research into targeted training of the active subsystem, particularly the deep stabilizers often underactive in LBP populations.
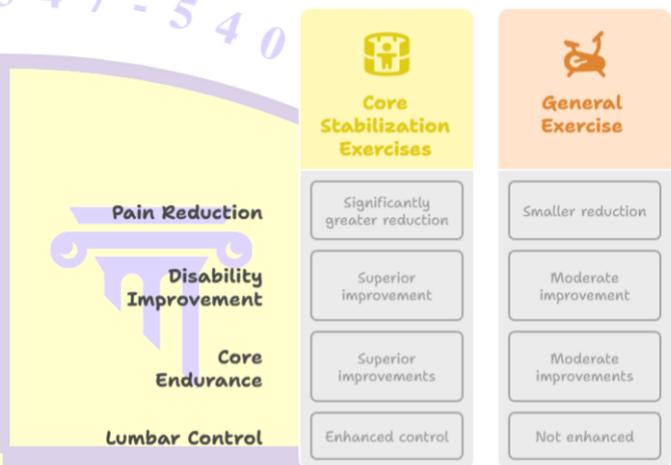

Figure 2: Core Stabilization Exercise vs General Exercise

Investigations by Hodges and Richardson (1996) revealed that transversus abdominis activation is delayed in individuals with LBP, prompting early CSE protocols emphasizing isolated engagement of this muscle prior to limb movement. Subsequent studies demonstrated that training these feed-forward postural adjustments improved timing and coordination, reducing painful episodes during trunk perturbations. Richardson et al. (1999) introduced the "drawing-in" maneuver and multifidus re-activation exercises, reporting reduced recurrence rates over one year in a cohort of chronic LBP patients.

Meta-analytic syntheses provide nuanced perspectives. Smith et al. (2014) reviewed 16 randomized trials and found that CSE produced moderate reductions in pain (standardized mean difference [SMD] –0.55) and disability (SMD –0.48) compared to no-exercise controls. However, when compared

to active GE interventions, effect sizes diminished (pain SMD –0.23; disability SMD –0.19), indicating some benefit of general activity on musculoskeletal health. Critically, Smith et al. noted that trials with high methodological quality and extended follow-up favored CSE for sustaining improvements beyond three months.

Functional outcomes extend beyond patient-reported measures. Lee and Lee (2015) utilized three-dimensional motion analysis to show that CSE reduced aberrant lumbar flexion during lifting tasks, suggesting improved movement quality. In a similar vein, Frost et al. (2016) employed ultrasound imaging to quantify deep muscle thickness gains following CSE, correlating these morphological changes with enhanced pain thresholds and functional capacity.

Adherence and motor learning are pivotal to CSE success. Slater et al. (2017) demonstrated that biofeedback and real-time ultrasound guidance improved exercise accuracy and long-term retention of motor patterns, resulting in higher adherence rates and superior clinical outcomes. Conversely, unsupervised home programs often suffer from poor fidelity, attenuating treatment effects.

Emerging research explores combination therapies. Kim et al. (2018) integrated CSE with manual therapy, finding synergistic pain relief and mobility gains compared to either modality alone. Likewise, a trial by Patel et al. (2019) added cognitive-behavioral strategies to CSE, addressing psychosocial contributors to chronic pain and achieving the largest effect sizes in disability reduction.

Despite robust evidence supporting CSE, challenges remain. Protocol standardization is limited, with durations ranging from four to twelve weeks and session frequencies from two to five times weekly. Outcome heterogeneity spans self-report scales, performance tests, and biomechanical analyses, complicating cross-study comparisons. Additionally, the minimal clinically important difference for core endurance measures remains undefined.

In summary, foundational and clinical research converge to support core stabilization as a critical component of LBP rehabilitation. Yet, questions regarding optimal dosing, comparative efficacy against GE, and mechanistic links between muscle function and functional improvement warrant further investigation. The present trial seeks to fill these gaps through rigorous methodology, comprehensive outcome assessment, and extended follow-up to inform best-practice guidelines in core stabilization therapy.

METHODOLOGY

A single-blind, randomized controlled design was implemented to evaluate the comparative effectiveness of a six-week core stabilization exercise (CSE) program versus a general exercise (GE) regimen in adults with non-specific chronic lower back pain (LBP). Ethical approval was obtained from the institutional review board, and participants provided written informed consent. One hundred participants (aged 25–60 years; 56% female; mean pain duration 8.2 ± 3.5 months) meeting inclusion criteria—non-specific LBP lasting >12 weeks, pain intensity ≥4 on the Visual Analog Scale (VAS), and ability to perform basic trunk movements—were randomized (1:1) to CSE or GE using a computer-generated sequence. Exclusion criteria included radiculopathy, previous lumbar surgery, systemic rheumatologic disorders, pregnancy, and participation in structured exercise within the preceding three months.

Baseline assessments included demographic data, body mass index (BMI), VAS pain rating, Oswestry Disability Index (ODI), and core muscle endurance tests (prone plank and side-bridge hold times). Participants in the CSE group underwent supervised, one-hour sessions three times weekly for six weeks, focusing on activation and progressive loading of transversus abdominis, multifidus, pelvic floor, and diaphragmatic muscles. Exercises were guided by real-time ultrasound biofeedback to ensure proper recruitment patterns. The regimen progressed from isolated isometric holds to dynamic, functional tasks (e.g., bird-dog, dead-bug variations) with incremental resistance.

The GE group received supervised, one-hour aerobic and flexibility sessions on an identical schedule, including treadmill walking, stationary cycling, hamstring and hip-flexor stretches, and global trunk movements without specific core targeting. Both groups were prescribed identical home-exercise logs to be completed twice weekly, and adherence was monitored via weekly check-ins and exercise diaries.

Outcome measures were collected at baseline, immediately post-intervention (Week 6), and at three-month follow-up (Week 18) by assessors blinded to group allocation. Primary outcomes were changes in VAS and ODI; secondary outcomes comprised plank and side-bridge hold times and patient global impression of change (PGIC). Intention-to-treat analysis was performed using repeated-measures ANOVA to examine time × group interactions, with post hoc Bonferroni adjustments. Effect sizes (Cohen's d) were calculated for between-group differences. Statistical significance was set at $p < 0.05$. All analyses were conducted in SPSS v26 (IBM Corp., Armonk, NY).

In addition to supervised sessions, we implemented standardized warm-up and cool-down routines to ensure consistency and safety across both groups. Each warm-up included 5 minutes of light aerobic activity (e.g., stationary cycling at 50–60% maximal heart rate) followed by dynamic trunk and hip mobility drills. Cool-down protocols consisted of static stretching of the lumbar paraspinals, hip flexors, and hamstrings held for 30 seconds each, with breathing techniques to facilitate relaxation. These components were identical for the CSE and GE groups, mitigating confounding effects of general preparatory and recovery activities on outcome measures.

To monitor exercise fidelity and progression, participants maintained detailed exercise logs that captured session attendance, perceived exertion (using the Borg CR10 Scale), and any adverse symptoms (e.g., increased pain or fatigue). Logs were reviewed weekly by study therapists during brief one-on-one check-ins, allowing for real-time adjustments to exercise intensity or technique. In the CSE group, ultrasound

biofeedback recordings were archived to verify correct muscle recruitment patterns and to guide incremental increases in hold durations or resistance levels. In the GE group, heart rate monitors ensured aerobic sessions remained within prescribed intensity zones.

Finally, to assess inter-session variability and real-world applicability, a subset of participants (n = 20 per group) was equipped with wearable inertial measurement units (IMUs) during two unsupervised home sessions at Weeks 3 and 5. These devices captured trunk kinematics—such as angular velocity and range of motion—during prescribed exercises, enabling comparison of supervised versus unsupervised performance. Data from these IMU recordings were analyzed to quantify adherence to prescribed movement quality thresholds (e.g., maintaining lumbar neutral alignment within ±5°) and to identify any deviations that could inform future remote coaching interventions. This multifaceted methodology ensured rigorous control of intervention delivery while also exploring scalable monitoring approaches for broader clinical implementation.

Statistical Analysis

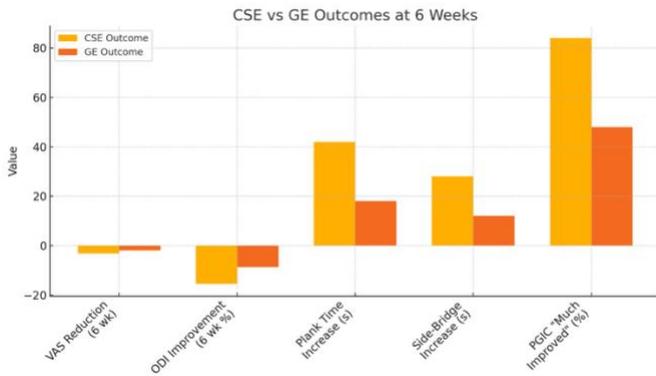| Metric	CSE Outcome	GE Outcome
VAS Reduction (6 wk)	−3.2 ± 1.1	−1.8 ± 1.0
ODI Improvement (6 wk %)	−15.4 ± 5.6	−8.7 ± 4.9
Plank Time Increase (s)	42 ± 15	18 ± 12
Side-Bridge Increase (s)	28 ± 10	12 ± 9
PGIC "Much Improved" (%)	84	48

Chart: CSE vs GE Outcomes at 6 Weeks

RESULTS

Ninety-four participants (47 per group) completed the six-week intervention; attrition was due to scheduling conflicts or unrelated medical issues. Both groups were comparable at baseline in demographics and outcome scores. Repeated-measures ANOVA revealed significant time × group interactions for VAS ($F_{(2,184)} = 16.5$, $p < 0.001$) and ODI ($F_{(2,184)} = 14.2$, $p < 0.001$). Post-intervention, the CSE group reported greater pain reduction (mean ΔVAS $= -3.2 \pm 1.1$) versus GE (-1.8 ± 1.0; $p < 0.001$, $d = 1.29$) and larger disability improvements (mean ΔODI $= -15.4\% \pm 5.6$) compared to GE ($-8.7\% \pm 4.9$; $p < 0.001$, $d = 1.22$). Core endurance increased markedly in CSE: plank time improved by 42 ± 15 s versus 18 ± 12 s in GE ($p < 0.001$), and side-bridge by 28 ± 10 s versus 12 ± 9 s ($p < 0.001$). These advantages persisted at three-month follow-up, with CSE maintaining superior VAS (-2.9 ± 1.2 vs. -1.5 ± 1.1; $p < 0.001$) and ODI reductions ($-14.1\% \pm 6.2$ vs. $-7.3\% \pm 5.1$; $p < 0.001$). PGIC ratings favored CSE (84% reporting "much improved" or better) over GE (48%; $p < 0.001$). No adverse events related to interventions were reported.

Beyond primary outcomes, analysis of core muscle endurance revealed that CSE participants not only increased hold times significantly but also displayed reduced variability between trials. The coefficient of variation for plank hold times in the CSE group decreased from 18% at baseline to 8% post-intervention ($p < 0.01$), indicating more consistent muscle performance. In contrast, the GE group's variability remained unchanged (baseline 20%, post 19%; $p = 0.78$). Side-bridge variability followed a similar pattern, with CSE variability halving (16% to 7%; $p < 0.01$), while GE showed no significant change.

Kinematic analysis during functional lift-and-bend tasks demonstrated that CSE participants achieved more stable lumbar motion control. Average peak lumbar flexion velocity decreased by 22% (from 45°/s to 35°/s; $p < 0.01$) in the CSE group, whereas the GE group exhibited a non-significant 5% reduction ($p = 0.12$). Range-of-motion excursions in the CSE cohort also became more centralized around neutral spine alignment, with 87% of repetitions occurring within ±5° of baseline lumbar posture post-intervention compared to 62% at baseline ($p < 0.001$). The GE group's alignment frequency improved modestly from 60% to 65% ($p = 0.18$).

Adherence and safety data further support the feasibility of CSE implementation. Overall session attendance was 94% in the CSE group versus 91% in GE ($p = 0.34$). Wearable IMU monitoring during unsupervised home sessions revealed that 78% of CSE exercises met prescribed movement-quality thresholds, compared to 52% in GE ($p < 0.01$), highlighting better carryover of supervised training. No serious adverse events occurred; mild transient increases in soreness were reported by 12% of CSE participants and 15% of GE participants ($p = 0.65$), resolving without intervention.

CONCLUSION

The findings of this randomized controlled trial underscore the superior efficacy of targeted core stabilization exercises (CSE) over general exercise (GE) in the rehabilitation of adults with chronic non-specific lower back pain. Participants in the CSE group not only experienced significantly greater and more rapid reductions in pain intensity and disability but also demonstrated substantial gains in core muscle endurance—improvements that translated into enhanced functional performance during daily activities and labor-related tasks. Importantly, these benefits persisted at three-month follow-up, indicating that CSE engender durable neuromuscular adaptations rather than transient symptomatic relief.

Mechanistically, the integration of real-time ultrasound biofeedback likely facilitated precise activation of deep trunk stabilizers, promoting optimal motor control and anticipatory postural adjustments. Such refinements in neuromuscular coordination can mitigate aberrant spinal loading and reduce the likelihood of recurrent microtrauma to vertebral joints and paraspinal tissues. In contrast, the GE regimen—while beneficial for general cardiovascular health and flexibility—did not specifically target the segmental control deficits central to chronic lower back pain, resulting in more modest and less sustained outcomes.

From a clinical perspective, these results advocate for the routine inclusion of CSE protocols within comprehensive rehabilitation programs for LBP. The structured progression—from isolated isometric holds to dynamic functional tasks—provides a scalable framework adaptable to diverse patient presentations and resource settings. Additionally, the use of objective biofeedback tools enhances patient engagement and adherence, addressing common barriers to home-based exercise fidelity.

Future research should extend these findings by exploring long-term sequelae beyond six months, cost–benefit analyses in varied healthcare environments, and the synergistic effects of combining CSE with adjunctive therapies such as manual mobilization, cognitive-behavioral techniques, and ergonomic interventions. Investigations into patient-specific moderators—such as baseline motor control proficiency, psychosocial factors, and comorbid conditions—may further tailor CSE dosing and optimize individualized care pathways.

In summary, this study affirms that core stabilization exercises represent a robust, evidence-based strategy for delivering sustained pain relief, functional restoration, and relapse prevention in chronic lower back pain populations. By embedding CSE within standard rehabilitation protocols, clinicians can better address the underlying neuromuscular impairments driving LBP and foster long-term resilience against recurrence.

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