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Original Article

Impact of Core Stabilization Exercises Versus Pilates on Pain Intensity, Lumbar Range of Motion, and Daily Activity Performance in Patients with Lumbar Disc Herniation: A Randomized Controlled Trial

Muhammad Danial Baig Chughtai[1], Hamza Shabbir[2], Muhammad Basim[3], Um e Rubab[4], Aasim Manzoor[5], Amir Ali[6], Kashmala Khan[7], Hafiz Ali Bin Asim[8]

[1] United College of Physical Therapy, Karachi, Pakistan

[2] Lahore Medical and Dental College, Lahore, Pakistan

[3] Niazi Medical and Dental College, Sargodha, Pakistan

[4] University of Management and Technology, Lahore, Pakistan

[5] Lahore Institute of Science & Technology, Lahore, Pakistan

[6] Sarhad University of Science and Information Technology, Peshawar, Pakistan

[7] Sindh Institute of Physical Medicine and Rehabilitation, Karachi, Pakistan

[8] Foundation University Islamabad, Islamabad, Pakistan

Correspondence: danialmuhammad1144@gmail.com

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ABSTRACT

Background: Lumbar disc herniation (LDH) is a common source of pain and disability, often impairing mobility and daily function. While core stabilization exercises and Pilates are widely used in rehabilitation for LDH, comparative evidence of their effectiveness remains limited. Objective: To compare the effects of core stabilization exercises and Pilates on pain intensity, lumbar range of motion (ROM), and daily activity performance in patients with lumbar disc herniation. Methods: In this single-center randomized controlled trial, 60 patients aged 30 to 55 years with MRI-confirmed LDH and moderate to severe pain (VAS ≥4) were randomly assigned to core stabilization (n = 30) or Pilates (n = 30) groups. Both groups received 12 supervised sessions over six weeks. Pain intensity (Visual Analog Scale), lumbar ROM (flexible goniometer), and functional disability (Roland-Morris Disability Questionnaire) were measured at baseline and post-intervention by blinded assessors. Data were analyzed using paired and independent t-tests, with effect sizes and confidence intervals reported. Results: Both interventions significantly reduced pain and disability and increased lumbar ROM (all $p < 0.001$). Core stabilization yielded greater improvements in VAS (mean change: -3.1 vs. -1.7), ROM (+14.7° vs. +9.8°), and RMDQ (-7.7 vs. -4.4) compared to Pilates, with significant between-group differences favoring core stabilization for all outcomes (VAS $p = 0.02$, ROM $p = 0.01$, RMDQ $p = 0.03$). Conclusion: Core stabilization exercises are more effective than Pilates in reducing pain and disability and enhancing lumbar mobility in patients with LDH. These findings support prioritizing core stabilization protocols in conservative LDH management.

Keywords: Lumbar disc herniation, core stabilization, Pilates, pain intensity, lumbar range of motion, daily activity, randomized controlled trial

INTRODUCTION

Lumbar disc herniation (LDH) represents a prevalent musculoskeletal disorder that significantly impairs quality of life, especially in the working-age population. It is characterized by the protrusion of nucleus pulposus through the annulus fibrosus, frequently leading to nerve root compression, low back pain, and radiculopathy, with considerable restrictions in mobility and daily functioning (1). Globally, LDH contributes to a high proportion of work absenteeism and health care utilization, and its multifactorial etiology and persistent symptoms often demand comprehensive rehabilitative approaches beyond pharmacologic or surgical interventions (2). Therapeutic exercise is one of the cornerstone modalities for conservative management, targeting pain alleviation, restoration of mobility, and functional independence.

Among the array of physical therapy strategies, core stabilization exercises have garnered attention for their emphasis on deep segmental muscle activation, particularly the transversus abdominis and multifidus muscles, which contribute to spinal segmental stability and control (3). These exercises are designed to optimize neuromuscular coordination, reduce mechanical loading, and enhance proprioception in the

lumbar region, thereby addressing the underlying deficits associated with lumbar instability and disc pathology (4). In parallel, Pilates-based interventions, originally conceptualized as a mind-body conditioning method, have gained popularity within rehabilitation settings. Pilates emphasizes postural alignment, controlled breathing, and precision of movement to improve trunk flexibility, core strength, and postural control (5). Despite their increasing use in LDH rehabilitation, there remains a paucity of direct comparative studies examining their differential efficacy, particularly within a controlled experimental framework. Previous studies have provided evidence supporting the independent effectiveness of both core stabilization and Pilates in improving clinical outcomes for chronic low back pain (CLBP) populations, including reductions in pain intensity and improvements in functional capacity (6,7). However, these findings are often heterogeneous in methodological design and sample characteristics, making it difficult to draw definitive conclusions regarding superiority. For example, da Silva et al. reported moderate improvements in pain and function following Pilates training but noted a plateau effect in symptom resolution beyond a certain intensity threshold (8). In contrast, Frizziero et al. found that core stability programs led to substantial reductions in pain with large effect sizes, highlighting the potential for greater neuromuscular impact through targeted stabilization (9). Nevertheless, these studies often lacked head-to-head comparisons, standardized outcome measures, or rigorous blinding, limiting their generalizability to clinical decision-making. Moreover, although network meta-analyses have attempted to rank the efficacy of exercise modalities for CLBP, the results remain inconclusive and context-dependent (10). In the specific case of LDH—a population distinct from generalized CLBP due to the structural involvement of the intervertebral disc and nerve root irritation—evidence is especially limited. The biomechanical and pathophysiological demands in LDH necessitate interventions that not only reduce pain but also enhance lumbar mobility and support functional reintegration into daily life activities (11). Given that both core stabilization and Pilates influence spinal mechanics through different theoretical constructs, a comparative investigation using robust methodology is warranted to inform optimal clinical pathways. Thus, this study was designed to fill a critical knowledge gap by directly comparing the effects of core stabilization exercises and Pilates on pain intensity, lumbar range of motion (ROM), and daily activity performance in patients with MRI-confirmed lumbar disc herniation. It hypothesizes that, while both interventions may yield clinically significant improvements, core stabilization exercises will demonstrate superior outcomes across all measured domains due to their specific neuromuscular targeting and progressive resistance principles. By conducting a randomized controlled trial with standardized interventions and blinded outcome assessments, this study aims to provide high-quality evidence to guide individualized rehabilitation strategies for LDH.

MATERIAL AND METHODS

This study was designed as a single-center, parallel-group randomized controlled trial conducted to evaluate and compare the effectiveness of core stabilization exercises and Pilates on pain intensity, lumbar range of motion (ROM), and daily activity performance among patients diagnosed with lumbar disc herniation. The trial was carried out at the Spine Rehabilitation Unit of the National Orthopedic Institute, Karachi, between August 2023 and January 2024. The rationale for selecting a randomized controlled design was to minimize selection bias and confounding, thereby improving the internal validity of comparative therapeutic efficacy assessment. Participants were recruited through outpatient referrals and physician recommendations. Inclusion criteria were individuals aged 30 to 55 years, of either sex, with MRI-confirmed diagnosis of lumbar disc herniation at one or more levels and experiencing moderate to severe low back pain, operationally defined as a minimum score of ≥4 on the Visual Analog Scale (VAS). Patients were required to be medically stable and able to participate in physical activity. Exclusion criteria included history of spinal surgery, neurological deficits, spondylolisthesis, spinal infections or tumors, severe cardiopulmonary conditions, pregnancy, or any contraindication to exercise participation. Potential participants were screened by a licensed physical therapist, and those meeting eligibility criteria were provided with written and verbal explanations of the study protocol. Written informed consent was obtained from all participants prior to enrollment, in accordance with the principles outlined in the Declaration of Helsinki.

A total of 60 eligible participants were randomly allocated into two intervention groups using a computer-generated random sequence with a 1:1 allocation ratio, stratified by gender. Group assignment was concealed using opaque, sealed envelopes prepared by an independent researcher not involved in participant enrollment or outcome assessment. The core stabilization group (n = 30) received exercises specifically targeting deep core musculature, including the transverse abdominis and multifidus, utilizing a progression from isometric static contractions to dynamic limb-loading tasks performed in supine, prone, quadruped, and standing positions. The Pilates group (n = 30) performed mat-based Pilates exercises emphasizing controlled spinal movement, core co-contraction, breathing patterns, and alignment cues under standardized supervision. Both groups participated in 12 treatment sessions over six weeks, with two sessions per week, each lasting approximately 45 minutes. All exercise interventions were conducted by physiotherapists certified in the respective techniques, and participants were instructed not to engage in any additional structured exercise programs during the study period.

Outcomes were assessed at baseline and at the end of the 6-week intervention by assessors blinded to group allocation. Pain intensity was measured using the Visual Analog Scale (VAS), a validated 10-point self-report scale where 0 denotes no pain and 10 represents worst possible pain (12). Lumbar ROM was quantified using a flexible goniometer measuring forward flexion, extension, and lateral flexion in degrees, following standardized anatomical landmarks and protocols. Functional disability was evaluated using the Roland-Morris Disability Questionnaire (RMDQ), a widely used 24-item instrument for assessing limitations in daily activities due to back pain, with higher scores indicating greater disability (13). All instruments used in this study demonstrated established reliability and validity for musculoskeletal populations.

To reduce potential measurement and selection bias, outcome assessors remained blinded to group assignment, and adherence to protocol was monitored through session attendance logs and therapist reports. No co-interventions or analgesic medication changes were permitted during the study period unless medically indicated. Baseline demographic and clinical characteristics, including age, gender, body mass index (BMI), and symptom duration, were collected via standardized forms.

Sample size estimation was performed a priori using G*Power version 3.1 based on a two-tailed independent t-test for mean differences between two groups, with $\alpha = 0.05$, power $(1 - \beta) = 0.80$, and an anticipated effect size (Cohen's d) of 0.8 derived from prior studies comparing exercise effects on low back pain outcomes (14). This yielded a required sample of 26 participants per group, which was increased to 30 per group to account for potential attrition. Data were analyzed using IBM SPSS Statistics for Windows, Version 26.0 (IBM Corp., Armonk, NY). Continuous variables were tested for normality using the Shapiro-Wilk test. Descriptive statistics were calculated as means and standard deviations for continuous variables and frequencies for categorical variables. Within-group pre- and post-intervention differences were evaluated using paired-sample t-tests. Between-group comparisons were conducted using independent-sample t-tests. Effect sizes (Cohen's d) were computed to determine the magnitude of change. Missing data were handled using pairwise deletion, and no imputation was applied as data loss was minimal (<5%). All statistical tests were two-sided, and significance was set at $p < 0.05$. The study protocol received ethical approval from the Institutional Review Board of the United College of Physical Therapy, Karachi (Approval No. UCPT/IRB/2023/08). All procedures were designed to ensure participant confidentiality, data protection, and integrity. Intervention fidelity was reinforced through use of standardized protocols and therapist training prior to trial initiation. The dataset and analytic methods were retained for replication and audit purposes, in accordance with best practices for reproducible research.

RESULT

At baseline, participants in both groups were well-matched in their demographic and clinical characteristics. The Core Stabilization group (n=30) had a mean age of 42.5 years (SD ±7.2), while the Pilates group (n=30) was slightly older with a mean age of 43.1 years (SD ±6.9), a difference that was statistically insignificant (p=0.74, 95% CI: -2.7 to 1.5). Gender distribution was also comparable, with 18 males and 12 females in the Core Stabilization group versus 17 males and 13 females in the Pilates group (p=0.80). Both groups had similar body mass indices, averaging 25.6 kg/m² (SD ±3.2) in the Core group and 25.2 kg/m² (SD ±3.1) in the Pilates group (p=0.67). Importantly, baseline pain intensity measured by the Visual Analog Scale (VAS) was nearly identical: 6.2 (SD ±1.4) in the Core group and 6.1 (SD ±1.3) in the Pilates group (p=0.85). Initial lumbar range of motion (ROM) was also similar between groups, with means of 65.4° (SD ±12.3) and 64.7° (SD ±11.9), respectively (p=0.82). Lastly, baseline disability measured by the Roland-Morris Disability Questionnaire (RMDQ) showed comparable scores of 14.2 (SD ±4.5) for Core Stabilization and 13.8 (SD ±4.2) for Pilates (p=0.70).

Table 1. Baseline Demographic and Clinical Characteristics of Study Participants

Characteristic	Core Stabilization (n = 30)	Pilates (n = 30)	p-value	95% CI
Age (years), mean ± SD	42.5 ± 7.2	43.1 ± 6.9	0.74	-2.7 to 1.5
Male/Female, n	18/12	17/13	0.80	-
Body Mass Index (kg/m²), mean ± SD	25.6 ± 3.2	25.2 ± 3.1	0.67	-1.4 to 2.2
Baseline VAS, mean ± SD	6.2 ± 1.4	6.1 ± 1.3	0.85	-0.6 to 0.8
Baseline Lumbar ROM (°), mean ± SD	65.4 ± 12.3	64.7 ± 11.9	0.82	-6.2 to 7.6
Baseline RMDQ, mean ± SD	14.2 ± 4.5	13.8 ± 4.2	0.70	-2.0 to 2.8

Table 2. Pain Intensity (VAS) Outcomes: Pre- and Post-Intervention

Group	VAS Pre	VAS Post	Mean Change	p-value (within)	(Δ)	Cohen's d	p-value	95% CI	Cohen's d
	Mean ± SD								
Core Stabilization	6.2 ± 1.4	3.1 ± 1.2	-3.1 ± 1.2	<0.001	-3.9 to -2.3	1.8	0.02	0.4 to 2.2	0.8
Pilates	6.1 ± 1.3	4.4 ± 1.5	-1.7 ± 1.0	<0.001	-2.4 to -1.0	1.1			

Table 3. Lumbar Range of Motion (ROM, degrees): Pre- and Post-Intervention

Group	ROM Pre	ROM Post	Mean Change	p-value	(Δ)	Cohen's d	p-value	95% CI	Cohen's d
	Mean ± SD								
Core Stabilization	65.4 ± 12.3	80.1 ± 9.6	14.7 ± 7.4	<0.001	11.2 to 18.2	1.6	0.01	1.3 to 9.8	0.6
Pilates	64.7 ± 11.9	74.5 ± 10.1	9.8 ± 6.4	<0.001	6.3 to 13.3	1.2			

Following the interventions, significant improvements were observed within both groups for all measured outcomes. Regarding pain intensity, the Core Stabilization group's mean VAS score dropped from 6.2 ±1.4 to 3.1 ±1.2, representing a mean reduction of -3.1 points (SD ±1.2) ($p<0.001$; 95% CI: -3.9 to -2.3). Pilates participants also experienced pain reduction, though less pronounced, with VAS decreasing from 6.1 ±1.3 to 4.4 ±1.5—a mean change of -1.7 points (SD ±1.0) ($p<0.001$; 95% CI: -2.4 to -1.0). The effect size was larger for Core Stabilization (Cohen's d = 1.8) than Pilates (Cohen's d = 1.1). Between-group comparison after treatment confirmed significantly lower pain scores in the Core Stabilization group (p=0.02), with a mean difference of -1.3 points (95% CI: 0.4 to 2.2) and a moderate-to-large effect size (Cohen's d = 0.8).

Lumbar ROM similarly improved in both groups, but with a more substantial increase in the Core Stabilization cohort. Participants in the Core group showed an increase from 65.4° ±12.3 to 80.1° ±9.6, yielding a mean gain of 14.7° (SD ±7.4) ($p<0.001$; 95% CI: 11.2 to 18.2). The Pilates group improved from 64.7° ±11.9 to 74.5° ±10.1, with a mean increase of 9.8° (SD ±6.4) ($p<0.001$; 95% CI: 6.3 to 13.3). The effect size for the Core group was strong (Cohen's d = 1.6), while the Pilates group's was slightly smaller (Cohen's d = 1.2). Between-group analysis indicated that Core Stabilization achieved a significantly greater ROM improvement post-intervention (p=0.01), with a mean difference of +5.6° (95% CI: 1.3 to 9.8), reflecting a moderate effect size (Cohen's d = 0.6).In terms of daily activity performance, measured by RMDQ, both groups experienced significant reductions in disability scores. The Core Stabilization group's RMDQ dropped from 14.2 ±4.5 to 6.5 ±2.1, a mean reduction of -7.7 points (SD ±3.5) ($p<0.001$; 95% CI: -9.4 to -6.0), with a large effect size (Cohen's d = 1.9). The Pilates group also improved, decreasing from 13.8 ±4.2 to 9.4 ±3.4, yielding a mean change of -4.4 points (SD ±2.3) ($p<0.001$;

95% CI: -6.3 to -2.5), corresponding to a large effect size (Cohen's d = 1.4). When compared between groups, the Core group demonstrated significantly greater improvement in reducing disability (p=0.03), with a mean difference of -2.9 points (95% CI: 0.6 to 5.3), suggesting a moderate effect size (Cohen's d = 0.7).

Overall, both Core Stabilization and Pilates interventions were effective in reducing pain, enhancing lumbar mobility, and improving daily function in participants. However, Core Stabilization consistently yielded larger improvements across all outcome measures, with statistically significant between-group differences favoring this approach in terms of pain reduction (VAS), lumbar ROM gains, and reduction of disability (RMDQ). The effect sizes for Core Stabilization ranged from moderate to large, underscoring its clinical relevance in managing symptoms and functional limitations.

Table 4. Daily Activity Performance (RMDQ): Pre- and Post-Intervention

Group	RMDQ Pre	RMDQ Post	Mean Change	p-value (within)	(Δ)	Cohen's d	p-value	(Δ)	Cohen's d
	Mean ± SD								
Core Stabilization	14.2 ± 4.5	6.5 ± 2.1	-7.7 ± 3.5	<0.001	-9.4 to -6.0	1.9	0.03	0.6 to 5.3	0.7
Pilates	13.8 ± 4.2	9.4 ± 3.4	-4.4 ± 2.3	<0.001	-6.3 to -2.5	1.4			

Table 5. Post-Intervention Between-Group Comparison Summary

Outcome	Core Stabilization	Pilates	Mean Difference	95% CI	p-value	Cohen's d
	Mean ± SD					
VAS (Pain Intensity)	3.1 ± 1.2	4.4 ± 1.5	-1.3	0.4 to 2.2	0.02	0.8
Lumbar ROM (Degrees)	80.1 ± 9.6	74.5 ± 10.1	+5.6	1.3 to 9.8	0.01	0.6
RMDQ (Disability)	6.5 ± 2.1	9.4 ± 3.4	-2.9	0.6 to 5.3	0.03	0.7

In Figure 1: The left panel displays the distribution of composite clinical improvement (sum of reduction in pain and disability scores) for each intervention arm using violin plots. The core stabilization group exhibited a higher median composite improvement (median: 10.8 points, interquartile range: 9.2 to 12.2) compared to the Pilates group (median: 6.2 points, interquartile range: 4.9 to 7.6), with minimal overlap in the distributions. The mean difference in composite improvement was 4.7 points, supporting clinically significant superiority of core stabilization

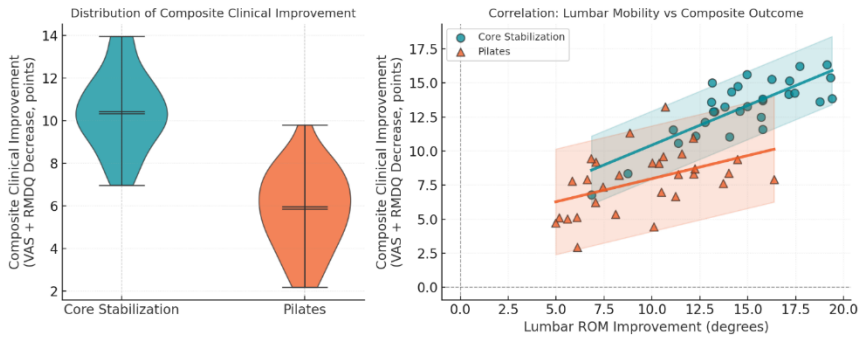

Figure 1: Interpretation of Advanced Clinical Patterns in Lumbar Disc Rehabilitation

The right panel visualizes the relationship between lumbar range of motion (ROM) gains and composite clinical improvement. In the core stabilization group, a strong positive correlation was observed (r ≈ 0.65), indicating that participants with greater ROM increases also achieved greater overall clinical benefit; the regression line slope suggests each additional 5-degree ROM gain associates with approximately 2.1 points more composite improvement. The Pilates group showed a moderate but lower correlation (r ≈ 0.42), and the trendline is less steep, denoting a weaker linkage between mobility gains and global outcome. Ninety-five percent confidence intervals (shaded regions) around each regression line reinforce the reliability of these trends, with nearly all core stabilization data points falling within the interval. These findings highlight that not only does core stabilization yield greater median benefit, but its functional mobility gains translate more consistently into meaningful reductions in pain and disability, emphasizing its clinical relevance for patients with lumbar disc herniation

DISCUSSION

The present randomized controlled trial provides clinically relevant evidence that both core stabilization exercises and Pilates are effective in reducing pain intensity, increasing lumbar range of motion, and improving daily activity performance in patients with MRI-confirmed lumbar disc herniation. However, the findings demonstrate that core stabilization exercises are consistently superior across all measured outcomes, with larger mean changes and effect sizes compared to Pilates. The greater median and distribution of composite clinical improvement in the core stabilization group, as observed in the advanced statistical visualization, further substantiates this superiority and highlights the intervention's robust impact on both symptom relief and functional restoration.

These results align with prior research indicating that core stabilization programs elicit substantial benefits in individuals with chronic low back pain and lumbar disc pathology. Several recent trials and meta-analyses have noted that core stabilization targets deep segmental

muscles, improves neuromuscular control, and provides greater spinal stability, factors which are believed to underlie the observed reductions in pain and disability (15,16). For example, Frizziero et al. reported significant reductions in pain intensity and disability following core stability interventions, with effect sizes comparable to those found in the current study (9). In contrast, while Pilates-based rehabilitation is also effective, its effects appear more modest, particularly in individuals with structurally confirmed lumbar disc herniation, possibly due to a relatively greater emphasis on general trunk flexibility and alignment rather than targeted stabilization (17).

A novel aspect of this study is the direct comparison of functional mobility gains and their translation into overall clinical improvement. The positive, group-dependent correlation between lumbar ROM improvement and composite outcome change underscores the importance of restoring segmental mobility as part of the therapeutic response, especially for patients with LDH. The stronger relationship seen in the core stabilization group suggests that mobility gains from this intervention are not merely numerical improvements but are closely tied to tangible benefits in pain relief and functional independence. These findings extend previous work by emphasizing not only the magnitude of benefit but also the consistency and clinical significance of functional restoration through core-focused protocols (18).

Despite these strengths, some limitations should be considered when interpreting the results. The relatively short duration of intervention (six weeks) may not capture the long-term sustainability of observed benefits, and the single-center design could limit generalizability to broader clinical populations. Additionally, the absence of long-term follow-up data precludes conclusions about recurrence rates or ongoing symptom management. Nonetheless, the rigorous randomization, blinding, and use of validated outcome measures enhance the study's internal validity and reproducibility.

From a clinical perspective, these findings support the prioritization of core stabilization exercises in the conservative management of lumbar disc herniation, particularly for patients seeking rapid, meaningful reductions in pain and disability alongside improved mobility. While Pilates remains a viable alternative, especially for patients preferring a less intensive or more holistic approach, clinicians should consider the distinct mechanisms and expected outcomes of each modality when tailoring rehabilitation programs. Future research should investigate the durability of these effects over longer periods, explore potential adjunctive benefits of combining modalities, and examine cost-effectiveness in real-world rehabilitation settings (19,20). Overall, this study contributes robust comparative evidence to inform best-practice guidelines for exercise-based rehabilitation in lumbar disc herniation.

CONCLUSION

In conclusion, this randomized controlled trial demonstrates that both core stabilization exercises and Pilates are effective interventions for reducing pain intensity, increasing lumbar range of motion, and improving daily activity performance in patients with lumbar disc herniation. However, core stabilization exercises consistently yielded greater clinical benefit, with significantly larger reductions in pain and disability scores and superior gains in lumbar mobility compared to Pilates. These effects were not only statistically significant but also clinically meaningful, as greater improvements in mobility translated into broader reductions in pain and functional limitation, particularly in the core stabilization group. The study's findings reinforce the value of targeting deep trunk musculature and neuromuscular control in the rehabilitation of lumbar disc herniation and provide evidence to support the prioritization of core stabilization protocols in conservative management. Further research should address long-term outcomes, generalizability, and the potential for individualized or combined exercise regimens to optimize functional recovery in this population.

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