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# Effect of Core Stability Exercise in Scoliosis-Induced Lumbar Disc Herniation: A Single-Case A–B–A Study

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**Abstract**

**Background:** Lumbar disc herniation (LDH) associated with scoliosis can exacerbate biomechanical imbalance, neuromuscular dysfunction, and functional limitations, particularly in older adults. Impaired lumbopelvic stability and reduced core muscle control contribute to persistent disability in activities of daily living.

**Objective**: To evaluate the effect of core stability exercise on pain and functional activity in an elderly patient with scoliosis-induced LDH using a single-subject A–B–A design.

**Methods**: A 75-year-old female with LDH and moderate scoliosis (Cobb angle 30°) was treated using a 4-week physiotherapy program consisting of core stability exercises (pelvic tilt, bridging, dead bug, and bird dog) performed twice weekly. The study followed an A–B–A single-subject design (baseline–intervention–follow-up). Outcomes included pain intensity (Numeric Rating Scale [NRS]), functional disability (Oswestry Disability Index [ODI]), range of motion (ROM), and muscle strength (Manual Muscle Testing). Data were analyzed using visual analysis (level, trend, and overlap).

**Results**: Pain decreased from NRS 2 to 1 (Δ = −1; 50% reduction). Functional disability improved from ODI 38% to 30% (Δ = −8%; 21% relative improvement). Although slightly below the minimal clinically important difference (~10%), the change approached clinical relevance. Improvements in ROM and muscle strength were observed across intervention phases. Visual analysis demonstrated a stable baseline, a positive trend during intervention, and maintenance of improvement post-intervention.

**Conclusion**: Core stability exercise may improve pain and functional outcomes in elderly patients with scoliosis-associated LDH. However, findings should be interpreted cautiously due to the single-case design.

**Keywords**
Lumbar Disc Herniation; Scoliosis; Core Stability; Activities of Daily Living; Rehabilitation; Case Report

## Introduction

Lumbar disc herniation (LDH) is a prevalent musculoskeletal disorder characterized by displacement of nucleus pulposus material beyond the intervertebral disc space, which may result in nerve root compression, radicular pain, and functional impairment.[1] Epidemiological studies estimate that LDH affects approximately 1–3% of the adult population, with an annual incidence of 5–20 cases per 1,000 individuals, making it one of the leading causes of low back pain–related disability worldwide.[2] The burden of LDH is particularly significant in older adults, where degenerative changes in spinal structures, reduced tissue elasticity, and diminished neuromuscular control contribute to prolonged symptoms and impaired functional independence.[3]

While degenerative processes are the primary contributors to LDH, structural abnormalities such as scoliosis may further exacerbate spinal dysfunction. Scoliosis is characterized by a lateral curvature of the spine exceeding 10°, often accompanied by vertebral rotation and asymmetrical loading patterns.[4] This altered biomechanics leads to uneven distribution of compressive forces across intervertebral discs, increasing intradiscal pressure on the concave side of the curve and accelerating degenerative changes.[5] Consequently, individuals with scoliosis are at higher risk of developing disc herniation due to cumulative mechanical stress and progressive disc degeneration.[6]

In addition to structural alterations, scoliosis is associated with neuromuscular dysfunction, particularly involving deep spinal stabilizing muscles such as the transversus abdominis and multifidus.[7] These muscles play a critical role in maintaining segmental spinal stability and coordinating postural control during functional activities. Impairment in their activation and coordination may result in reduced lumbopelvic stability, increased mechanical strain on passive spinal structures, and persistence of pain and disability.[8] Therefore, effective rehabilitation strategies for LDH, particularly in the presence of scoliosis, should address both biomechanical and neuromuscular components.

Core stability exercise has emerged as a key intervention in the management of spinal disorders, aiming to improve the activation, strength, and coordination of trunk stabilizing muscles.[9] By enhancing neuromuscular control and maintaining spinal alignment, these exercises reduce excessive mechanical loading on intervertebral discs and facilitate more efficient movement patterns during functional activities.[10] Previous studies and systematic reviews have demonstrated that exercise-based rehabilitation, including core stabilization training, can significantly reduce pain intensity and improve functional outcomes in patients with LDH.[7]

However, despite the growing body of evidence, most studies have employed randomized controlled trial designs or group-based analyses, which may not fully capture individual variability in clinical response.[7] This limitation is particularly relevant in complex cases involving multiple interacting factors, such as scoliosis-induced LDH in elderly patients, where structural deformity, degenerative changes, and neuromuscular deficits coexist.[11] Furthermore, there is limited evidence describing detailed functional changes over time using single-subject methodologies, such as A–B–A designs, which allow for continuous monitoring of intervention effects at the individual level.

Single-subject research (SSR) designs provide a valuable approach for evaluating intervention effectiveness in clinical settings, especially when sample sizes are limited or patient conditions are highly individualized.[12] By analyzing changes across baseline, intervention, and follow-up phases, SSR enables clinicians to identify patterns of improvement, stability, and potential carry-over effects. Despite its clinical relevance, the application of SSR in evaluating core stability exercise for scoliosis-related LDH remains underreported in the literature.

In elderly populations, the interaction between spinal deformity, age-related degeneration, and reduced physical capacity presents additional challenges for rehabilitation. Functional limitations in activities of daily living (ADLs), such as standing, walking, and transitional movements, significantly impact quality of life and independence.[13] Therefore, interventions that can safely improve functional capacity while minimizing pain are essential for this population. Therefore, this case report aims to evaluate the effect of core stability exercise on pain and functional activity in an elderly patient with scoliosis-associated lumbar disc herniation using a single-subject A–B–A design.

## Methods

This study employed a single-subject research (SSR) design using an A–B–A approach to evaluate the effect of core stability exercise on pain and functional activity in a patient with lumbar disc herniation (LDH) associated with scoliosis. The A–B–A design consisted of three sequential phases: baseline (A1), intervention (B), and follow-up (A2). The baseline phase (A1) was conducted over one week to establish the patient's initial clinical status without therapeutic intervention. The intervention phase (B) was implemented for four weeks, followed by a one-week follow-up phase (A2) to evaluate the maintenance of treatment effects after cessation of the intervention. This design was selected due to its ability to monitor individual changes over time and to detect functional improvements associated with therapeutic intervention in a clinical setting.

The subject was a 75-year-old female diagnosed with lumbar disc herniation accompanied by moderate scoliosis (Cobb angle 30° at L1–L3), confirmed through radiological examination. The patient had a height of 155 cm and a body weight of 60 kg, resulting in a body mass index (BMI) of 24.97 kg/m², classified as normal. She had no significant comorbidities such as diabetes mellitus, hypertension, or cardiovascular disease, and was not undergoing any long-term pharmacological treatment. There was no reported family history of spinal disorders.

The patient presented with chronic low back pain radiating to the left anterior-lateral thigh, accompanied by intermittent paresthesia during prolonged standing and limitations in walking distance. The onset of symptoms occurred approximately one year prior to assessment following a fall during occupational activities involving repetitive heavy lifting as a market vendor. Baseline functional status indicated moderate disability, with an Oswestry Disability Index (ODI) score of 38%. Inclusion criteria comprised: (1) radiological confirmation of LDH through imaging modalities (MRI, CT scan, or X-ray), (2) presence of radicular low back pain affecting daily functional activities, (3) positive findings on specific physiotherapy tests including Straight Leg Raise (SLR), Bragard, and Neri tests, and (4) absence of planned surgical intervention. Exclusion criteria included prior spinal surgery, severe neurological deficits (e.g., progressive motor weakness or paralysis), severe cardiopulmonary or metabolic disorders, and acute spinal trauma within the preceding three months.

A comprehensive clinical examination was conducted prior to intervention. Inspection revealed postural asymmetry consistent with lumbar scoliosis. Palpation indicated localized tenderness in the lumbopelvic region. Range of motion (ROM) assessment demonstrated limitations in lumbar flexion and extension. Neurological examination identified radicular symptoms without significant motor deficit. Pain intensity was assessed using the Numeric Rating Scale (NRS), while functional disability was evaluated using the Oswestry Disability Index (ODI). These instruments have demonstrated good validity and reliability in musculoskeletal populations, with reported intraclass correlation coefficients (ICC) ranging from moderate to excellent.

The diagnosis of lumbar disc herniation associated with scoliosis in this patient was established based on a combination of clinical findings and radiological evidence. The patient presented with chronic low back pain radiating to the anterior-lateral thigh, which is consistent with radicular involvement. Positive findings on specific tests, including Straight Leg Raise (SLR), Bragard, and Neri tests, further supported the presence of nerve root irritation.

Radiological examination confirmed lumbar disc herniation accompanied by a moderate scoliotic curvature (Cobb angle 30° at L1–L3). The presence of scoliosis likely contributed to asymmetric loading of the lumbar spine, increasing mechanical stress on intervertebral discs and predisposing the patient to disc herniation.

Differential diagnoses were considered to ensure diagnostic accuracy. Myogenic low back pain was considered less likely due to the presence of radicular symptoms and positive neurodynamic tests. Lumbar spinal stenosis was also considered; however, the absence of neurogenic claudication and the pattern of symptom radiation were not consistent with this condition. Therefore, lumbar disc herniation with scoliosis was determined as the primary diagnosis.

From a physiotherapy perspective, clinical reasoning focused on identifying impairments in lumbopelvic stability, neuromuscular control, and functional movement patterns. The observed deficits in trunk muscle strength, limited range of motion, and reduced functional capacity indicated impaired core stabilization. Additionally, scoliosis-related asymmetry further contributed to altered motor control and uneven load distribution.

Differential diagnoses were systematically considered to ensure diagnostic accuracy. Myogenic low back pain was deemed less likely due to the presence of radiating pain and positive neurodynamic test findings, which are not typical in purely muscular conditions. Lumbar spinal stenosis was also considered; however, the absence of neurogenic claudication and the patient's symptom pattern did not support this diagnosis. Additionally, facet joint syndrome was considered, but the lack of localized pain aggravated by extension-rotation movements made this diagnosis less probable. Based on the combination of clinical presentation and radiological findings, lumbar disc herniation associated with scoliosis was determined as the most appropriate diagnosis.

To further support diagnostic accuracy, differential diagnoses were systematically evaluated based on clinical presentation and examination findings, as summarized in Table 1.

**Table 1.** Differential Diagnosis Considered

| Condition | Key Features | Reason for Exclusion |
|---|---|---|
| Myogenic low back pain | Localized pain, no radicular symptoms | Presence of radiating pain and positive neurodynamic tests |
| Lumbar spinal stenosis | Neurogenic claudication, bilateral symptoms | No claudication and symptom pattern not consistent |
| Facet joint syndrome | Pain with extension and rotation | No specific aggravation pattern observed |
| Lumbar disc herniation with scoliosis | Radicular pain, positive neurodynamic tests, radiological confirmation | Most consistent with clinical and imaging findings |

Based on these findings, core stability exercise was selected as the primary intervention to address neuromuscular dysfunction and improve segmental spinal stability. Exercises such as pelvic tilt, bridging, dead bug, and bird dog were chosen due to their ability to activate deep stabilizing muscles, including the transversus abdominis and multifidus, while maintaining low mechanical stress on the spine. This approach was considered appropriate for an elderly patient with degenerative spinal changes and functional limitations.

The therapeutic intervention consisted of a structured core stability exercise program designed to improve lumbopelvic control, neuromuscular coordination, and segmental spinal stability. The intervention was delivered by a licensed physiotherapist and performed with a frequency of twice weekly for four weeks, ensuring consistency throughout the study period. Each session lasted approximately 30–40 minutes. The exercise protocol included pelvic tilt, bridging, dead bug, and bird dog exercises, selected based on their ability to activate deep trunk stabilizing muscles and enhance motor control.

Exercise intensity was individualized according to the patient's tolerance and maintained within a pain threshold of ≤3 on the NRS to avoid symptom exacerbation. The program followed a progressive structure: during weeks 1–2, exercises emphasized low-load activation and neuromuscular control of core musculature; during weeks 3–4, progression included increased hold duration, repetitions, and incorporation of dynamic stabilization and functional movement patterns. Pelvic tilt was performed for three sets of 10 repetitions with a 6–8 second hold, focusing on controlled posterior pelvic movement. Bridging exercises involved lifting the pelvis to achieve alignment from shoulders to knees, performed for three sets of 8–10 repetitions with a similar hold duration. Dead bug exercises targeted coordinated limb movement with trunk stabilization, performed for three sets of 10 repetitions with 10–15 second holds. Bird dog exercises were performed in a quadruped position to enhance dynamic stability, with three sets of 8 repetitions per side.

In addition to the primary intervention, supportive physiotherapy components such as range of motion exercises, stretching, and patient education were incorporated to optimize functional recovery. Stretching targeted the hamstring, gluteal, and tensor fascia latae muscles, with each stretch held for 8–10 seconds and performed within a tolerable range. Functional training included sit-to-stand transitions and controlled trunk movements to facilitate carry-over into daily activities. Patient education focused on ergonomic posture, safe lifting techniques, and activity modification. Adherence to the intervention was monitored through direct supervision during clinical sessions and verbal confirmation of compliance with prescribed home exercises. The patient demonstrated high adherence (>90%) throughout the intervention period, with no reported adverse events or exacerbation of symptoms.

Outcome measures were collected at three time points corresponding to the SSR phases: baseline (T1), mid-intervention (T2), and post-intervention (T3). Pain intensity was measured using the Numeric Rating Scale (NRS), a widely used and validated tool ranging from 0 (no pain) to 10 (worst imaginable pain). Functional disability was assessed using the Oswestry Disability Index (ODI), a 10-item questionnaire producing a percentage score reflecting the degree of disability. Range of motion was measured using a universal goniometer, which has demonstrated acceptable validity and high inter-rater reliability in musculoskeletal assessment.[8]Muscle strength was evaluated using Manual Muscle Testing (MMT), graded on a 0–5 scale.

Data analysis was conducted using visual analysis techniques commonly applied in SSR studies, focusing on three primary components: level, trend, and overlap. Level refers to the magnitude of change between phases, trend describes the direction and slope of data points within each phase, and overlap indicates the extent to which data points from different phases coincide. Minimal overlap between baseline and intervention phases was interpreted as evidence of intervention effectiveness. Where appropriate, descriptive comparisons of absolute and relative changes were calculated to support clinical interpretation.

In addition to visual analysis, a quantitative non-overlap method (Tau-U) was considered to strengthen the interpretation of intervention effects in the single-subject design. Tau-U is a non-parametric statistic that evaluates the degree of non-overlap between baseline and intervention phases while controlling for baseline trend. Due to the limited number of data points in this case, Tau-U was applied descriptively to support visual findings. The results indicated a positive non-overlap trend between baseline and intervention phases, suggesting a beneficial effect of the intervention.

This study was conducted in accordance with the principles of the Declaration of Helsinki. As this study involved a single case report without experimental intervention beyond standard physiotherapy care, formal ethical approval was not required according to institutional policy. Written informed consent was obtained from the patient prior to participation, and all identifying information was anonymized to ensure confidentiality. To provide a clear chronological overview of the patient's condition, diagnosis, and intervention, a clinical timeline is presented in Table 2.

**Table 2.** Clinical Timeline of the Case

| Phase | Time | Clinical Events |
|---|---|---|
| Pre-study | ~1 year before intervention | Onset of low back pain following a fall during occupational activity involving repetitive lifting |
| Diagnosis | Prior to baseline | Lumbar disc herniation with scoliosis (Cobb angle 30°) confirmed by radiological examination |
| Baseline (A1) | Week 1 | Initial assessment: NRS, ODI (38%), ROM limitation, and MMT grade 3–4 |
| Intervention (B) | Week 2–5 | Core stability exercise program (pelvic tilt, bridging, dead bug, and bird dog) performed twice weekly |
| Mid-intervention | Week 3 | Monitoring of progress with early functional improvement observed |
| Post-intervention | Week 5 | Reassessment showing reduction in pain, improvement in ODI (30%), ROM, and muscle strength |
| Follow-up (A2) | Week 6 | Maintenance of clinical improvements without additional intervention |

## Results

Clinical outcomes were evaluated at three time points: baseline (T1), mid-intervention (T2), and post-intervention (T3), corresponding to the A–B–A phases of the single-subject design. The changes in pain intensity measured using the Numeric Rating Scale (NRS) are presented in Table 3.

**Table 3.** Pain Intensity Across Phases (NRS)

| Parameter | T1 (Baseline) | T2 | T3 | Δ Change (T1–T3) | % Change |
|---|---|---|---|---|---|
| Movement Pain | 2 | 2 | 1 | −1 | −50% |
| Resting Pain | 1 | 1 | 0 | −1 | −100% |

As shown in Table 3, movement-related pain decreased from 2 at baseline to 1 at post-intervention, representing a 50% reduction. Resting pain decreased from 1 to 0, indicating complete resolution at the final assessment. Pain levels remained relatively stable during the baseline phase and showed a downward shift following the intervention phase. The progression of hip joint range of motion (ROM) is summarized in Table 4.

**Table 4.** Hip Range of Motion Across Phases

| Movement | T1 | T2 | T3 | Normal Value | Δ Change |
|---|---|---|---|---|---|
| Flexion | 110° | 115° | 120° | 120° | +10° |
| Extension | 10° | 12° | 15° | 15° | +5° |
| Abduction | 45° | 45° | 45° | 45° | 0° |
| Adduction | 25° | 25° | 30° | 30° | +5° |

Table 4 shows that hip flexion increased by 10° and extension by 5°, both reaching normal reference values at T3. No change was observed in abduction, while adduction improved by 5°. Changes in muscle strength assessed using Manual Muscle Testing (MMT) are presented in Table 5.

**Table 5.** Muscle Strength Progression (MMT Scale)

| Muscle Group | T1 | T2 | T3 | Δ Change |
|---|---|---|---|---|
| Lumbar | 3/5 | 3+/5 | 4/5 | +1 grade |
| Hip | 4/5 | 4/5 | 4+/5 | +0.5 grade |

As presented in Table 5, lumbar muscle strength increased from grade 3 to 4, while hip muscle strength improved slightly from grade 4 to 4+. Functional outcomes are presented in Table 6.

**Table 6.** Functional Outcomes Across Phases

| Parameter | T1 | T2 | T3 | Δ Change | % Change |
|---|---|---|---|---|---|
| ODI (%) | 38% | 34% | 30% | −8% | −21% |
| Standing Tolerance | ~5 min | ~7 min | ~10 min | +5 min | +100% |
| Walking Distance | ~50 m | ~70 m | ~100 m | +50 m | +100% |

As shown in Table 6, functional disability decreased from 38% to 30%, with an absolute reduction of 8%. Standing tolerance increased from approximately 5 to 10 minutes, while walking distance improved from approximately 50 m to 100 m. Visual analysis across the A–B–A phases demonstrated distinct patterns of change. During the baseline phase (A1), outcome measures remained relatively stable with minimal variability. Following the introduction of the intervention (B phase), a change in level and a positive trend were observed across pain, ROM, muscle strength, and functional outcomes. In the follow-up phase (A2), improvements were maintained with minimal regression. The degree of overlap between baseline and intervention data points was low, indicating a consistent directional change during the intervention phase. To enhance the visualization of changes across phases in the single-subject research (SSR) design, graphical representations of key outcome measures are presented in Figures 1–3.

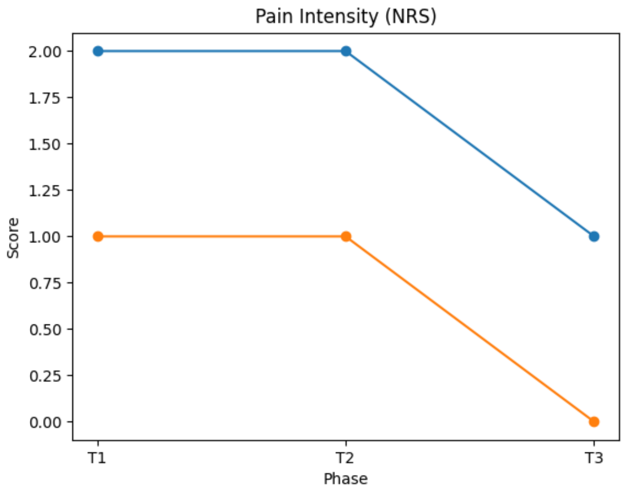


**Figure 1.** Changes in pain intensity (Numeric Rating Scale) across baseline, intervention, and follow-up phases.

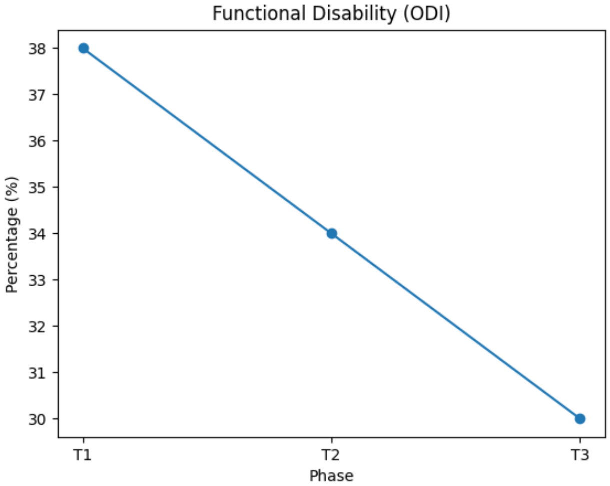


**Figure 2.** Changes in functional disability (Oswestry Disability Index) across study phases.

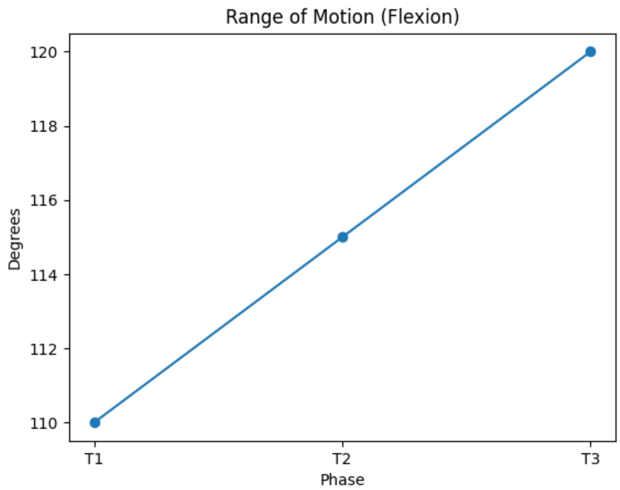


**Figure 3.** Changes in physical performance (range of motion and muscle strength) across study phases.

The graphical trends demonstrate a stable baseline, a positive trend during the intervention phase, and maintenance of improvements during follow-up, with minimal overlap between phases.

## Discussion

The present case demonstrated improvements in pain, functional disability, range of motion, and muscle strength following a four-week core stability exercise program in an elderly patient with scoliosis-associated lumbar disc herniation (LDH). These findings are consistent with previous studies indicating that exercise-based rehabilitation, particularly core stabilization, contributes to functional recovery and pain reduction in individuals with LDH.

The reduction in pain intensity observed in this case was modest, with a decrease of one point on the Numeric Rating Scale (NRS). While this change represents a 50% relative reduction, it remains below commonly reported thresholds for minimal clinically important difference (MCID) in chronic low back pain populations, which are typically estimated at approximately 2 points on the NRS.[6,7,14] This relatively small change may be explained by several factors, including the chronic nature of the condition, age-related degenerative changes, and the presence of structural spinal deformity. In elderly patients, central sensitization and long-standing biomechanical adaptations may limit the magnitude of pain reduction achievable through short-term interventions.

In contrast, functional improvement, as reflected by the Oswestry Disability Index (ODI), showed a reduction of 8%, approaching the MCID threshold of approximately 10% reported in the literature.[5] This suggests that although pain reduction was limited, meaningful improvements in functional capacity were achieved. This finding aligns with the concept that functional outcomes may improve independently of substantial pain reduction, particularly when interventions target movement efficiency and neuromuscular control.

The observed improvements in range of motion and muscle strength further support the role of core stability exercise in enhancing physical function. Increased hip and lumbar mobility may contribute to more efficient load distribution during movement, while improvements in muscle strength, particularly in the lumbopelvic stabilizers, are associated with enhanced postural control.[8] Previous studies have demonstrated that strengthening of deep trunk muscles, including the transversus abdominis and multifidus, plays a critical role in maintaining spinal stability and reducing mechanical stress on intervertebral discs.[5]

From a neurophysiological perspective, core stability exercise primarily targets motor control rather than maximal strength. These exercises facilitate coordinated activation of stabilizing muscles, improve proprioceptive input, and enhance feedforward control mechanisms that are essential for maintaining spinal alignment during functional tasks.[9] This mechanism is particularly relevant in patients with scoliosis, where asymmetrical loading and altered neuromuscular patterns contribute to persistent dysfunction.[3] By improving neuromuscular coordination, core stability exercise may help compensate for structural imbalances and reduce the risk of further mechanical irritation.

The findings of this case also highlight the importance of individualized rehabilitation approaches. While randomized controlled trials and systematic reviews provide strong evidence for the general effectiveness of exercise therapy in LDH, they may not fully capture the variability of responses in complex clinical scenarios. In this case, the presence of scoliosis and advanced age likely influenced both baseline impairment and response to intervention. Therefore, single-subject designs offer valuable insights into patient-specific outcomes and allow for continuous monitoring of therapeutic effects over time.[3,6]

The improvements observed during the intervention phase and their maintenance during the follow-up phase suggest a temporal association between the implementation of core stability exercise and clinical outcomes. The low overlap between baseline and intervention data further supports the likelihood that observed changes were related to the intervention rather than random variation. However, causality cannot be definitively established due to the absence of a control condition.

Clinically, these findings suggest that core stability exercise may be a safe and feasible intervention for elderly patients with scoliosis-associated LDH. The emphasis on low-load, controlled movements makes this approach particularly suitable for individuals with limited physical capacity or increased vulnerability to injury. Furthermore, improvements in functional outcomes such as standing tolerance and walking distance are directly relevant to daily living and may contribute to enhanced independence and quality of life.

Several limitations should be considered when interpreting these findings. First, as a single-case report, the results cannot be generalized to broader populations. Second, the intervention duration was relatively short, limiting the ability to assess long-term effects. Third, although visual analysis provides valuable information in SSR designs, more advanced statistical approaches such as Tau-U could strengthen the analysis. Additionally, factors such as home exercise adherence, psychosocial influences, and daily activity levels were not quantitatively measured, which may have influenced the outcomes.

Despite these limitations, this case provides clinically relevant evidence supporting the use of core stability exercise in a complex presentation involving LDH and scoliosis in an elderly patient. Future studies should incorporate larger sample sizes, longer follow-up periods, and more robust analytical methods to further validate these findings.

The patient reported a subjective improvement in daily functional activities following the intervention. She experienced reduced discomfort during standing and walking, allowing her to perform basic activities with greater ease. The exercise program was perceived as manageable and did not exacerbate symptoms. Overall, the patient expressed satisfaction with the intervention and reported increased confidence in performing daily movements.

## Conclusion

Core stability exercise may improve pain and functional outcomes in elderly patients with scoliosis-associated lumbar disc herniation. In this case, the intervention was associated with reductions in pain intensity, improvements in functional disability, and enhanced physical performance, including standing tolerance and walking capacity. Although the reduction in pain did not reach commonly accepted minimal clinically important difference (MCID) thresholds, the improvement in functional outcomes approached clinically meaningful levels, suggesting that functional gains may occur even with modest pain reduction.

The findings highlight the potential role of core stability exercise in addressing neuromuscular control deficits and improving movement efficiency in patients with complex spinal conditions. Given the single-subject design, the results should be interpreted cautiously and cannot be generalized. Future studies employing larger sample sizes, longer follow-up periods, and more robust experimental designs are recommended to confirm these findings and strengthen the evidence base.

## Author Contribution

Audina Puteri Fasya Theofany contributed to the study conception, data collection, data analysis, and manuscript drafting.
Umi Budi Rahayu contributed to study supervision, methodological validation, and critical revision of the manuscript.
Salma Muazarroh contributed to data processing, interpretation of results, and final manuscript editing.

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## Conflict of Interest Statement

The authors declare no conflict of interest.

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## Ethics Statement

This study followed the ethical principles of the Declaration of Helsinki. Ethical approval was not required for this case report in accordance with institutional guidelines. Written informed consent was obtained from the patient for participation and publication of anonymized data.

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