

Preoperative Physiotherapy versus No Preoperative Conditioning in Lumbar Spine Surgery: A Comparative Study of Pain, Mobility, and Functional Recovery

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Abstract

Background: Delayed functional recovery and persistent pain following lumbar spine surgery remain significant clinical concerns despite advances in surgical techniques. Preoperative physiotherapy (prehabilitation) has been proposed as a strategy to optimize physical preparedness and accelerate postoperative recovery; however, evidence regarding its effectiveness in lumbar spine surgery remains inconsistent. **Objective:** To compare the effects of structured preoperative physiotherapy versus no preoperative conditioning on postoperative pain, mobility, and functional recovery in patients undergoing elective lumbar spine surgery.

Methods: This prospective, randomized comparative study included 120 patients scheduled for elective lumbar spine surgery, who were allocated to either a prehabilitation group (PREHAB, n = 60) or a usual-care control group (NO PREHAB, n = 60). The PREHAB group participated in a six-week supervised physiotherapy program comprising aerobic conditioning, strengthening, lumbar stabilization exercises, flexibility training, and patient education, while the control group received standard preoperative care without structured physiotherapy. Primary outcome was functional disability assessed using the Oswestry Disability Index (ODI) at six weeks postoperatively. Secondary outcomes included pain intensity (Numeric Pain Rating Scale), functional mobility (Timed Up and Go test), functional exercise capacity (Six-Minute Walk Test), length of hospital stay, and postoperative opioid consumption. Outcomes were measured at baseline, preoperatively, and at 2 weeks, 6 weeks, and 3 months postoperatively.

Results: Baseline characteristics were comparable between groups. At six weeks postoperatively, the PREHAB group demonstrated significantly greater improvement in ODI compared with the NO PREHAB group (mean difference -8.5 points; $p < 0.001$), exceeding the minimal clinically important difference. The PREHAB group also reported significantly lower pain scores at two weeks postoperatively ($p < 0.001$) and demonstrated superior functional mobility and walking capacity at both six weeks and three months ($p < 0.01$). Additionally, patients in the PREHAB group had shorter hospital stays and reduced postoperative opioid requirements. No serious adverse events related to preoperative physiotherapy were reported.

Conclusion: Structured preoperative physiotherapy significantly enhances early postoperative recovery following lumbar spine surgery by reducing pain, improving mobility, and accelerating functional restoration. Incorporating prehabilitation into routine preoperative care pathways may represent a safe and effective strategy to optimize surgical outcomes.

Keywords: Preoperative physiotherapy, Prehabilitation, Lumbar spine surgery, Functional recovery, Pain management, Mobility, Rehabilitation

Introduction

Low-back pain and degenerative lumbar disorders represent a major cause of pain, disability, and reduced quality of life worldwide, and many patients with refractory symptoms undergo elective lumbar spine surgery (discectomy, decompression, and fusion) to relieve radicular pain and neurogenic claudication. Surgical treatment often leads to substantial symptom relief, but recovery is heterogeneous:

some patients experience prolonged pain, reduced mobility and delayed return to function despite technically successful surgery. Early postoperative pain, reduced walking capacity and delayed functional recovery increase healthcare utilization and can limit return to work and daily activities [1].

Preoperative optimization (prehabilitation) is an emerging strategy that aims to enhance patients' physical, functional, and psychological reserve prior to elective surgery so that they are better able to tolerate the surgical stress and recover more rapidly afterwards. Prehabilitation programs are typically multimodal and may include targeted strengthening and aerobic exercise, spinal stabilization and flexibility training, patient education about pain and recovery expectations, and psychological or behavioural components such as



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coping strategies or graded exposure [2]. The theoretical rationale is twofold:

- (1) increasing musculoskeletal capacity (strength, endurance, mobility) provides a larger functional reserve to withstand perioperative deconditioning, and
- (2) education and psychological preparation reduce Kinesio phobia and maladaptive pain behaviours that can slow recovery.

Interest in prehabilitation for spinal surgery has grown over the last decade and a small but growing body of randomized trials and feasibility studies has examined whether structured preoperative physiotherapy improves post-surgical pain, function, and mobility. The PREPAR randomized controlled trial- one of the largest, multimodal presurgical physiotherapy trials in degenerative lumbar spine disorders implemented a person-centered intervention combining supervised exercise, graded activity, and cognitive-behavioural elements and found meaningful improvements in preoperative function and some early postoperative outcomes, though long-term effects were less consistent. Other smaller RCTs and pilot studies (for example, exercise-based prehabilitation in lumbar spinal stenosis cohorts) have reported reductions in early postoperative pain and improvements in walking function and trunk muscle strength. However, individual trials vary in intervention dose, content, patient selection, and outcome timing, producing heterogeneity that complicates pooled interpretation [3].

Systematic reviews and meta-analyses to date provide mixed but cautiously optimistic conclusions. Some reviews report that prehabilitation can improve short-term postoperative pain and physical function after lumbar spine surgery, while others find limited or no clear added benefit, often citing heterogeneous interventions, small sample sizes, and variable outcome measurement as limiting factors. Recent comprehensive reviews emphasize that evidence is strongest for early (short-term) benefits, particularly reductions in immediate postoperative pain and modest functional gains but consistent, high-quality data demonstrating sustained long-term benefits (beyond 3–6 months) remain lacking. These uncertainties underscore the need for rigorously designed trials with standardized prehabilitation protocols, adequate sample size, blinded outcome assessment, and clearly prespecified endpoints.

Beyond clinical outcomes, practical questions remain regarding the optimal components (exercise type, intensity, frequency), timing (how many weeks before surgery), delivery mode (supervised vs. home-based or eHealth), and cost-effectiveness of prehabilitation in spine populations [4]. Trials such as PREPARE and several feasibility studies have demonstrated that structured, supervised programs are implementable in routine preoperative pathways and can be adapted to include remotely delivered components; nonetheless, robust economic evaluations and stratified analyses identifying which patient subgroups derive the greatest benefit are scarce. Clarifying these aspects is essential if prehabilitation is to be integrated widely into preoperative spine care pathways.

Given the clinical burden of prolonged postoperative pain and functional impairment after lumbar spine surgery and the promising yet heterogeneous evidence for prehabilitation, there is a clear rationale to compare structured preoperative physiotherapy versus usual preoperative care using standardized outcome measures focused on pain, mobility and functional recovery. The current study

(manuscript draft) was designed to address this gap by evaluating a multimodal, exercise-based prehabilitation program delivered in the six weeks prior to elective lumbar spine surgery and to examine short-term (2 and 6 weeks) and medium-term (3 months) effects on pain (NPRS), disability (Oswestry Disability Index), and performance-based mobility (Timed Up and Go, 6-minute walk test). The trial aims to provide clinically actionable data on the magnitude, timing, and clinical relevance of potential benefits from preoperative physiotherapy and to inform future larger definitive trials and implementation efforts.

Methods

Study design

This study was a prospective, parallel-group, randomized controlled comparative trial conducted in patients undergoing elective lumbar spine surgery. Participants were randomly assigned in a 1:1 ratio to either a prehabilitation group or a control group receiving usual preoperative care. Outcome assessments were performed at baseline, preoperatively, and during postoperative follow-up. The study design and reporting were guided by the CONSORT recommendations for randomized trials.

Study setting and duration

The study was conducted in an integrated orthopaedic and physiotherapy department. Recruitment occurred over an 18-month period, with postoperative follow-up completed at 3 months after surgery.

Participants

Inclusion criteria

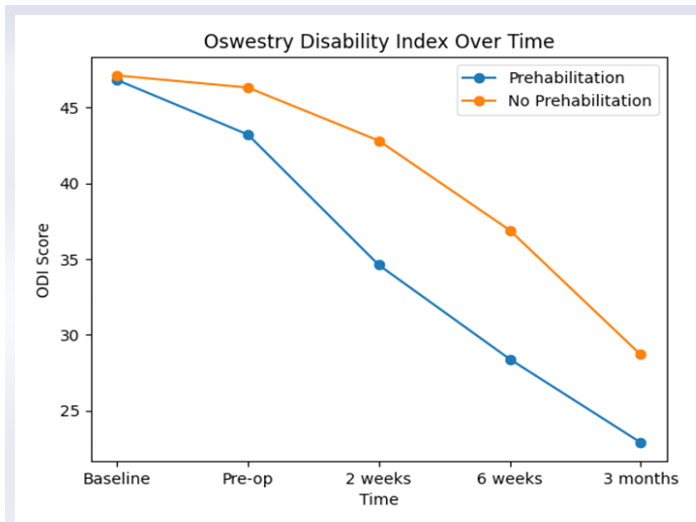
- Adults aged 18–75 years
- Diagnosed with degenerative lumbar spine pathology (lumbar disc herniation, lumbar canal stenosis, or degenerative spondylosis)
- Scheduled for elective single- or two-level lumbar decompression, discectomy, or decompression with fusion
- Baseline Oswestry Disability Index (ODI) \geq 20%
- Ability to ambulate independently (with or without assistive device)
- Willingness to participate in exercise-based physiotherapy

Exclusion criteria

- Emergency lumbar spine surgery
- Progressive neurological deficit requiring urgent intervention
- Previous lumbar spine surgery in the past 12 months
- Severe cardiopulmonary, neurological, or systemic disease contraindicating exercise
- Active spinal infection, tumour, or inflammatory spinal disease
- Cognitive impairment preventing understanding of instructions
- Participation in structured physiotherapy within 6 weeks prior to enrolment

Sample size

Sample size was calculated based on the primary outcome measure (ODI at 6 weeks postoperatively). Assuming a minimal clinically important difference of 8 points, a standard deviation of 14, power of 80%, and alpha level of 0.05, a minimum of 50 participants per group



Graph 1: Shows Faster and Greater Functional Recovery in the PREHAB group

was required. Allowing for a 20% attrition rate, the final target sample size was set at 120 participants (60 per group).

Randomization and allocation concealment

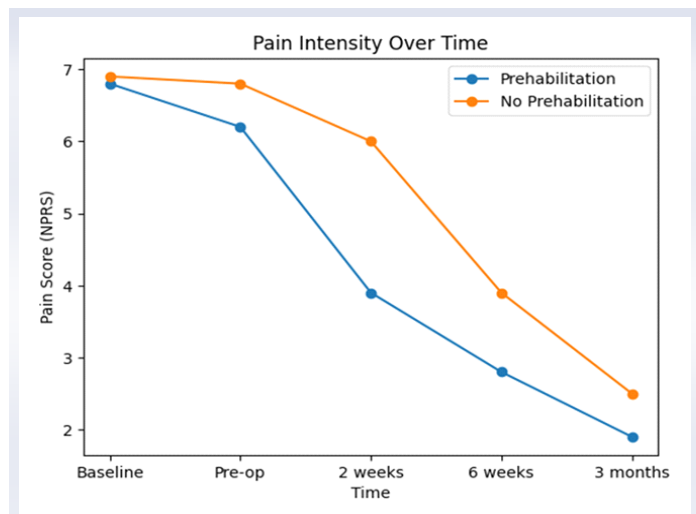
Eligible participants were randomly assigned in a 1:1 ratio to either the prehabilitation group or the control group using a computer-generated random sequence. Allocation concealment was achieved using sequentially numbered, opaque, sealed envelopes prepared by an independent researcher not involved in recruitment or assessment.

Interventions

Preoperative physiotherapy (PREHAB) group

Participants allocated to the PREHAB group underwent a structured, supervised prehabilitation program for 6 weeks prior to surgery. The program consisted of:

- Frequency: Two supervised sessions per week
- Session duration: 45–60 minutes
- Aerobic training: 15–20 minutes of treadmill walking or stationary cycling at moderate intensity (Rate of Perceived Exertion 11–13)
- Strengthening exercises: Progressive resistance exercises targeting



Graph 2: Showing early postoperative pain reduction with prehabilitation

Variable	PREHAB (n = 56)	NO PREHAB (n = 54)	p-value
Age (years)	57.2 ± 10.8	56.5 ± 11.3	0.68
Sex (Male/Female)	26 / 30	27 / 27	0.62
BMI (kg/m ²)	25.4 ± 3.2	25.7 ± 3.5	0.59
Duration of symptoms (months)	11.6 ± 4.9	12.1 ± 5.2	0.57
Baseline ODI (%)	46.8 ± 10.5	47.1 ± 11.0	0.86
Baseline NPRS	6.8 ± 1.2	6.9 ± 1.3	0.74
Surgical procedure (Decompression/Discectomy/Fusion)	22 / 20 / 14	24 / 18 / 12	0.83

trunk extensors and flexors, hip abductors, extensors, quadriceps, and calf muscles (2–3 sets of 8–12 repetitions)

- Lumbar stabilization training: Exercises focusing on deep trunk musculature (transversus abdominis and multifidus) using low-load motor control strategies
- Flexibility and mobility: Stretching of hamstrings, hip flexors, gluteal muscles, and thoracolumbar mobility drills
- Education component: One structured educational session covering spine anatomy, pain neuroscience, postoperative expectations, activity pacing, and importance of early mobilization
- Home exercise program: Participants were instructed to perform prescribed exercises on non-supervised days and maintain an exercise log

Exercise progression was individualized based on patient tolerance and symptom response. Adherence was monitored through attendance records and exercise logs.

Control group (NO PREHAB)

Participants in the control group received usual preoperative care, which included routine surgical counselling and general advice regarding activity and postoperative recovery. No supervised physiotherapy or structured exercise program was provided prior to surgery.

Surgical procedure and postoperative care

All surgeries were performed by experienced spine surgeons using standardized surgical techniques appropriate to the pathology. Postoperative analgesia, mobilization protocols, and in-hospital physiotherapy were standardized across both groups to minimize confounding effects.

Outcome measures

Primary outcome:

Time point	PREHAB (Mean ± SD)	NO PREHAB (Mean ± SD)	p-value
Baseline	46.8 ± 10.5	47.1 ± 11.0	0.86
Preoperative	43.2 ± 10.1	46.3 ± 10.8	0.04
2 weeks post-op	34.6 ± 11.8	42.8 ± 12.6	<0.001
6 weeks post-op	28.4 ± 12.1	36.9 ± 13.4	<0.001
3 months post-op	22.9 ± 11.3	28.7 ± 12.5	0.01

Time point	PREHAB	NO PREHAB	p-value
Baseline	6.8 ± 1.2	6.9 ± 1.3	0.74
Preoperative	6.2 ± 1.3	6.8 ± 1.4	0.02
2 weeks post-op	3.9 ± 1.5	6.0 ± 1.6	<0.001
6 weeks post-op	2.8 ± 1.3	3.9 ± 1.5	<0.001
3 months post-op	1.9 ± 1.2	2.5 ± 1.3	0.03

Oswestry Disability Index (ODI): Assessed functional disability related to low back pain. The primary endpoint was ODI score at 6 weeks postoperatively.

Secondary outcomes:

- Numeric Pain Rating Scale (NPRS): Measurement of pain intensity (0–10 scale)
- Timed Up and Go (TUG) test: Assessment of functional mobility
- Six-Minute Walk Test (6MWT): Measurement of functional exercise capacity
- Length of hospital stay: Number of postoperative inpatient days
- Postoperative opioid consumption: Morphine-equivalent dose in the first 48 hours
- Adverse events: Exercise-related or surgery-related complications

Results

Participation:

A total of 147 patients were screened for eligibility. Twenty-seven patients did not meet inclusion criteria or declined participation. One hundred and twenty participants were enrolled and randomized equally into the PREHAB group (n = 60) and NO PREHAB group (n = 60). During follow-up, four participants in the PREHAB group and six participants in the NO PREHAB group were lost to follow-up due to personal reasons or non-attendance. Data from 56 participants in the PREHAB group and 54 participants in the NO PREHAB group were included in the final analysis.

Baseline characteristics

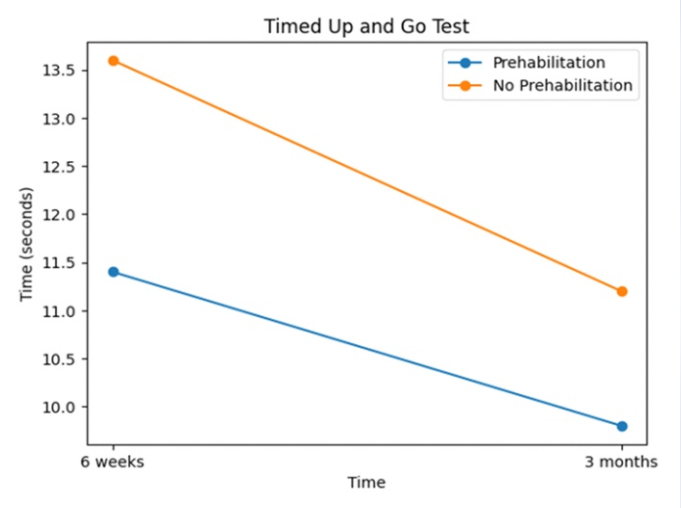
Baseline demographic and clinical characteristics were comparable between the two groups, with no statistically significant differences observed, indicating successful randomization. (Table 1)

Primary Outcome:

Oswestry Disability Index (ODI)

At 6 weeks postoperatively, the PREHAB group demonstrated significantly greater improvement in functional disability compared

Outcome	PREHAB	NO PREHAB	p-value
TUG at 6 weeks (s)	11.4 ± 2.8	13.6 ± 3.2	<0.001
TUG at 3 months (s)	9.8 ± 2.4	11.2 ± 2.6	0.002
Outcome	PREHAB	NO PREHAB	p-value



Graph 3: Showing Superior Mobility at 6 weeks and 3 months

to the NO PREHAB group (Table 2). The mean ODI score at 6 weeks was 28.4 ± 12.1 in the PREHAB group and 36.9 ± 13.4 in the NO PREHAB group, resulting in a mean between-group difference of -8.5 points (95% CI: -12.8 to -4.2; p < 0.001). The effect size was moderate (Cohen’s d = 0.65).

Repeated-measures ANOVA revealed a significant group × time interaction (p < 0.001), indicating a faster and greater functional recovery trajectory in the PREHAB group. (Table 2, Graph 1)

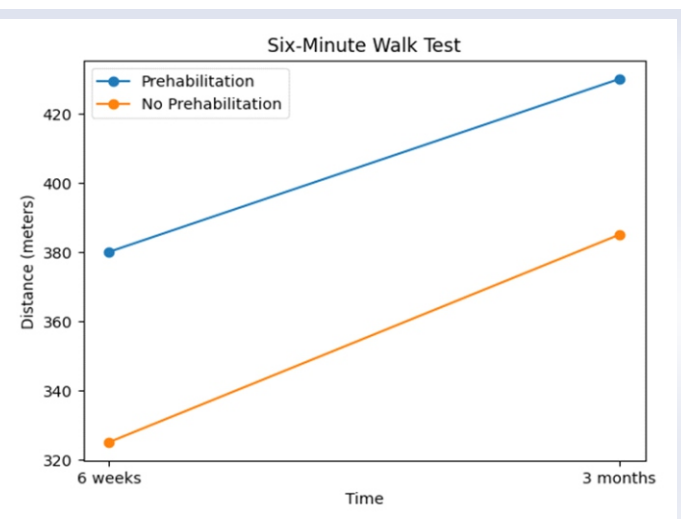
Secondary Outcomes

Pain intensity (NPRS)

Pain scores decreased in both groups following surgery; however, the PREHAB group experienced significantly lower pain intensity during the early postoperative period. At 2 weeks postoperatively, NPRS scores were 3.9 ± 1.5 in the PREHAB group compared to 6.0 ± 1.6 in the NO PREHAB group (p < 0.001), representing a clinically meaningful difference. (Table 3, Graph 2)

Functional mobility (TUG)

At 6 weeks postoperatively, participants in the PREHAB group completed the Timed Up and Go test significantly faster than those in



Graph 4: Shows better Functional exercise capacity in the PREHAB group

Table 5. Six-Minute Walk Test outcomes

Time point	PREHAB (m)	NO PREHAB (m)	p-value
6 weeks post-op	380 ± 75	325 ± 82	0.002
3 months post-op	430 ± 70	385 ± 78	0.004

the NO PREHAB group (11.4 ± 2.8 s vs. 13.6 ± 3.2 s; $p < 0.001$). (Table 4, Graph 3)

Functional exercise capacity (6MWT)

The PREHAB group demonstrated superior functional exercise capacity at both 6 weeks and 3 months postoperatively. At 6 weeks, the mean walking distance was 380 ± 75 m in the PREHAB group versus 325 ± 82 m in the NO PREHAB group ($p = 0.002$). (Table 5, Graph 4)

Length of hospital stay and opioid consumption

The median length of hospital stay was shorter in the PREHAB group compared to the NO PREHAB group (2 days [IQR 2–3] vs. 3 days [IQR 2–4]; $p = 0.04$). Total opioid consumption during the first 48 hours postoperatively was also lower in the PREHAB group (mean morphine equivalent dose 32.5 ± 9.4 mg vs. 41.8 ± 11.2 mg; $p < 0.001$).

Adverse events

No serious adverse events related to preoperative physiotherapy were reported. Mild transient muscle soreness was reported by 9 participants (16%) in the PREHAB group. Surgical complication rates were comparable between groups.

Discussion

The present comparative study evaluated the effect of structured preoperative physiotherapy on postoperative pain, mobility, and functional recovery in patients undergoing elective lumbar spine surgery. The findings demonstrate that patients who participated in a six-week prehabilitation program experienced significantly greater improvements in functional disability, pain intensity, and performance-based mobility outcomes compared to patients who received usual preoperative care alone. Importantly, the magnitude of improvement was most pronounced during the early postoperative period, suggesting that preoperative conditioning plays a critical role in accelerating recovery rather than altering long-term surgical outcomes [7, 8].

Interpretation of primary outcome

Functional disability, assessed using the Oswestry Disability Index, showed a statistically and clinically meaningful between-group difference at six weeks postoperatively. The observed mean difference of approximately 8–9 points exceed commonly reported minimal clinically important difference thresholds for ODI in lumbar spine populations, indicating that the improvement was not only statistically significant but also clinically relevant. This faster reduction in disability suggests that patients who enter surgery with

better physical conditioning and understanding of postoperative expectations are more capable of resuming daily activities earlier following surgery.

These findings are consistent with results from the PREPARE randomized controlled trial, which reported improved preoperative function and a trend toward better early postoperative outcomes in patients receiving person-centered presurgical physiotherapy. While long-term differences tend to diminish over time, early functional recovery is of particular importance because it influences hospital stay, rehabilitation trajectory, and patient satisfaction.

Pain outcomes and early recovery

Pain intensity decreased in both groups following surgery; however, the prehabilitation group demonstrated significantly lower pain scores during the early postoperative phase. The difference observed at two weeks postoperatively exceeded the minimal clinically important difference for the Numeric Pain Rating Scale, suggesting meaningful pain modulation. Reduced early postoperative pain may be attributed to several mechanisms, including improved trunk muscle endurance, enhanced neuromuscular control, reduced fear-avoidance behaviours, and better patient education regarding movement and pain expectations.

Previous studies have highlighted the role of preoperative education and exercise in modulating central pain processing and reducing catastrophization. Patients who understand the expected postoperative course and are confident in movement strategies may be less likely to restrict activity unnecessarily, thereby reducing pain amplification associated with immobility and fear.

Mobility and functional performance

Performance-based mobility outcomes further support the benefits of prehabilitation. The prehabilitation group demonstrated superior Timed Up and Go performance and greater six-minute walk distances at both six weeks and three months postoperatively. These findings indicate that preoperative physiotherapy contributes to improved functional reserve, allowing patients to tolerate postoperative deconditioning more effectively and regain mobility faster [11].

Improvements in walking capacity are particularly relevant in lumbar spine populations, where reduced ambulation is a common limiting factor after surgery. Enhanced lower-limb strength, aerobic capacity, and trunk stabilization achieved during prehabilitation likely contributed to improved gait efficiency and endurance. Similar improvements in walking ability have been reported in trials focusing on exercise-based prehabilitation for lumbar spinal stenosis and degenerative lumbar disorders [15].

Length of hospital stay and healthcare utilization

Patients in the prehabilitation group demonstrated a shorter length of hospital stay and reduced postoperative opioid consumption. These findings have important implications for healthcare resource utilization and postoperative safety. Reduced opioid requirements may reflect lower pain intensity, improved coping strategies, and greater confidence in early mobilization. Shorter hospital stays can translate into reduced healthcare costs and lower risk of hospital-acquired complications.

Clinical implications

The results of this study support the integration of structured preoperative physiotherapy into routine care pathways for patients scheduled for elective lumbar spine surgery. From a physiotherapy perspective, prehabilitation offers an opportunity to assess baseline function, address movement dysfunctions, educate patients, and establish therapeutic rapport prior to surgery. For spine surgeons, collaboration with physiotherapists in the preoperative phase may enhance postoperative recovery without altering surgical technique or increasing perioperative risk [17, 18].

Importantly, the intervention used in this study was feasible, safe, and did not require highly specialized equipment, making it adaptable to a wide range of clinical settings, including resource-limited environments.

Limitations

Several limitations should be considered when interpreting these findings. First, although outcome assessors were blinded, participants and treating therapists could not be blinded due to the nature of the intervention, which may introduce performance bias. Second, the study was conducted at a single center, potentially limiting generalizability. Third, long-term outcomes beyond three months were not assessed, and therefore the durability of benefits remains uncertain. Finally, psychological variables such as fear-avoidance beliefs and pain catastrophization were not formally measured, despite their potential role in mediating outcomes.

Future research directions

Future multicenter trials with larger sample sizes and longer follow-up periods are warranted to determine whether early postoperative benefits of prehabilitation translate into sustained long-term improvements. Further research should also explore

optimal program duration, intensity, and delivery methods, including home-based and digitally supported prehabilitation models. Incorporating cost-effectiveness analyses and subgroup analyses may help identify patients most likely to benefit from preoperative physiotherapy.

Conclusion

This comparative study demonstrates that structured preoperative physiotherapy provides meaningful benefits in patients undergoing elective lumbar spine surgery. Participants who received a six-week prehabilitation program experienced significantly greater reductions in pain, faster improvement in functional mobility, and superior recovery of functional ability compared with those who received usual preoperative care alone.

The most prominent benefits were observed during the early postoperative period, where improved pain control, enhanced mobility, reduced opioid consumption, and shorter hospital stay were evident. These findings suggest that preoperative physiotherapy primarily accelerates recovery and improves early postoperative efficiency rather than altering the fundamental surgical outcome.

From a clinical perspective, integrating preoperative physiotherapy into routine surgical care pathways represents a safe, feasible, and cost-conscious strategy to optimize postoperative recovery. Collaborative preoperative planning between spine surgeons and physiotherapists may enhance patient preparedness, reduce postoperative morbidity, and improve overall rehabilitation outcomes.

Future large-scale, multicentre trials with longer follow-up and economic evaluation are warranted to further define optimal prehabilitation protocols and to establish their long-term value in lumbar spine surgery populations.

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Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given his/her consent for his/her images and other clinical information to be reported in the Journal. The patient understands that his/her name and initials will not be published, and due efforts will be made to conceal his/her identity, but anonymity cannot be guaranteed.

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