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Original Article

Correlation Between Preoperative Frailty Index and Functional Recovery After Lumbar Decompression Surgery in Elderly Patients

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ABSTRACT

Background: Elderly patients undergoing lumbar decompression surgery show variable postoperative recovery, and chronological age alone may not adequately predict functional outcome. Frailty reflects reduced physiological reserve and may provide better risk stratification before surgery. Objective: To determine the association between preoperative frailty and postoperative functional recovery in elderly patients undergoing lumbar decompression surgery and to compare the predictive value of frailty with chronological age. Methods: This prospective cohort study included 170 patients aged 60 years or older undergoing lumbar decompression for lumbar spinal stenosis or low-grade spondylolisthesis. Frailty was assessed preoperatively using the Modified Frailty Index. Functional outcomes were measured using the Oswestry Disability Index, Visual Analog Scale pain score, walking distance, complications, and hospital stay at 1, 3, and 6 months. Multivariate logistic regression and ROC analysis were performed. Results: Patients were classified as non-frail (35%), pre-frail (46%), and frail (19%). Frail patients had higher complication rates than pre-frail and non-frail patients (25% vs 12% vs 7%, $p<0.01$) and longer hospital stay. At six months, ODI reduction was greatest in non-frail patients and lowest in frail patients (34.5 ± 8.7 vs 18.7 ± 7.9 points, $p<0.001$). Frailty independently predicted poor recovery (OR 3.5, 95% CI 1.8–6.8, $p<0.001$), whereas age was not significant. Conclusion: Preoperative frailty is a stronger predictor of postoperative recovery than chronological age and should be integrated into surgical assessment and counseling. Keywords: Frailty; lumbar decompression; elderly patients; functional recovery; Oswestry Disability Index; lumbar spinal stenosis.

INTRODUCTION

Lumbar spinal stenosis is a prevalent degenerative spinal disorder among older adults and commonly results from progressive changes in the intervertebral discs, facet joints, ligamentum flavum, and vertebral canal dimensions. Clinically, it is associated with low back pain, radicular leg pain, numbness, weakness, neurogenic claudication, restricted walking tolerance, and impaired daily function. When conservative strategies such as medication, physiotherapy, activity modification, and epidural interventions fail to provide adequate relief, lumbar decompression surgery is frequently considered to reduce neural compression and improve pain-related disability and mobility (1). However, chronological age alone does not adequately explain postoperative recovery after lumbar decompression. Patients of similar age may demonstrate markedly different surgical resilience, complication risk, rehabilitation

potential, and functional improvement. Frailty provides a more biologically meaningful construct because it reflects reduced physiological reserve and increased vulnerability to surgical stress. Frailty has been conceptualized both as a clinical phenotype characterized by weakness, exhaustion, slow gait, low activity, and weight loss, and as an accumulated deficit state reflecting the progressive burden of comorbidities and functional impairments over time (2,3).

The relevance of frailty to surgical outcomes has been established across older surgical populations. Previous evidence shows that frailty predicts postoperative complications, prolonged hospitalization, and institutional discharge more effectively than routine demographic assessment alone (4). The development and validation of practical surgical frailty tools, including the Risk Analysis Index, further strengthened the role of frailty screening in preoperative risk stratification and perioperative decision-making (5). In spine surgery specifically, frailty has increasingly been recognized as a clinically useful measure for identifying vulnerable patients before operative intervention (6).

Recent systematic evidence has shown that frailty is associated with adverse outcomes after degenerative spine surgery, including higher mortality, major complications, non-home discharge, reintubation, myocardial infarction, acute renal failure, and longer hospital stay (7). Modified frailty indices have also shown value in stratifying risk among elderly patients undergoing spinal procedures (8). In lumbar spondylolisthesis treated through a posterior surgical approach, frailty has been reported as an important predictor of early postoperative morbidity (9). In patients with symptomatic lumbar spinal stenosis, frailty has also been associated with clinically relevant differences in disease burden and postoperative outcome profiles, suggesting that biological reserve may influence not only perioperative safety but also functional recovery (10).

Despite these findings, the relationship between preoperative frailty and patient-centered functional recovery after lumbar decompression remains less clearly defined than its relationship with complications. Lumbar decompression can provide meaningful improvement in older adults, including those aged 70 years and above, and increased chronological age alone has not consistently predicted poor postoperative outcome (11). Recovery after stenosis surgery often occurs most prominently within the first 3 to 6 months, making this period clinically important for evaluating functional improvement (12). Even patients older than 80 years may benefit from decompression, although medical complications remain an important concern (13). Therefore, the key clinical question is not simply whether elderly patients can benefit from surgery, but which patients are most likely to achieve meaningful functional recovery.

Functional recovery after lumbar decompression should be assessed using outcomes that matter directly to patients, including disability reduction, pain relief, walking capacity, and restoration of daily activity. Evidence suggests that higher frailty may be associated with worse postoperative Oswestry Disability Index scores, poorer health-related quality of life, greater pain burden, and longer hospitalization after elective degenerative lumbar spine surgery (14). Nevertheless, reviews continue to describe patient-reported outcome evidence as comparatively heterogeneous, and prospective decompression-focused data remain limited, particularly in South Asian settings (7,14).

This evidence gap is especially relevant in Pakistan, where the elderly population is increasing while geriatric care infrastructure remains underdeveloped. Local evidence has demonstrated a substantial burden of non-communicable disease, functional impairment, and geriatric morbidity among older adults, while broader health-system analyses highlight persistent gaps in specialized geriatric services and age-sensitive perioperative care (15,16). In this context, frailty-based surgical assessment may provide a practical and clinically interpretable approach for improving patient selection, counseling, perioperative planning, and rehabilitation pathways in tertiary-care hospitals.

Therefore, this prospective cohort study aimed to determine the relationship between preoperative frailty, assessed using the Modified Frailty Index, and postoperative functional recovery among elderly

patients undergoing lumbar decompression surgery at selected tertiary hospitals in Lahore, Pakistan. The primary research question was whether higher preoperative frailty is associated with poorer functional recovery at six months after surgery, defined by improvement in disability, pain, and walking ability. The study further hypothesized that frailty would predict postoperative recovery, complications, and hospital stay more accurately than chronological age alone.

MATERIALS AND METHODS

This prospective cohort study was conducted to evaluate whether preoperative frailty predicts functional recovery after lumbar decompression surgery in elderly patients. The study was carried out in selected tertiary-care hospitals in Lahore, Pakistan, which function as referral centers for degenerative spinal disorders and provide operative care to elderly patients from urban and peri-urban populations. Patient recruitment was conducted over 18 months, from January 2024 to June 2025, and participants were followed prospectively for six months after surgery.

Eligible participants were men and women aged 60 years or older who were scheduled for lumbar decompression surgery for symptomatic lumbar spinal stenosis or low-grade spondylolisthesis after insufficient response to conservative management. Patients were excluded if they had a history of previous lumbar fusion or major spine surgery, severe cognitive impairment preventing informed consent or reliable outcome reporting, neurological disorders unrelated to lumbar spine disease, terminal illness with life expectancy less than six months, or active infection at the surgical site. Eligible patients were identified during preoperative clinic visits after clinical examination and review of imaging findings, including magnetic resonance imaging or computed tomography where clinically indicated.

A total of 210 patients were assessed for eligibility. After applying the inclusion and exclusion criteria, 180 patients were enrolled after written informed consent. Ten participants were lost to follow-up during the six-month postoperative period, and the final complete-case analysis included 170 patients. Baseline data were collected before surgery using structured case-record forms and included age, sex, body mass index, educational status, smoking status, diagnosis, comorbidities, American Society of Anesthesiologists physical status classification, baseline Oswestry Disability Index, Visual Analog Scale pain score, walking distance, lower-limb strength, and daily activity limitation.

Preoperative frailty was assessed using the Modified Frailty Index with 11 variables. Each deficit was recorded as present or absent, and the total score was used to classify patients as non-frail, pre-frail, or frail. Patients with scores of 0–1 were categorized as non-frail, those with scores of 2–3 as pre-frail, and those with scores of 4 or higher as frail. The primary exposure variable was frailty category before surgery. The primary outcome was functional recovery at six months, operationally defined using a combined clinical criterion of at least 30% improvement in Oswestry Disability Index, at least 3-point reduction in Visual Analog Scale pain score, and improvement in walking ability. Secondary outcomes included changes in ODI, VAS pain score, walking distance, postoperative complications, length of hospital stay, and discharge disposition.

All participants underwent posterior lumbar decompression performed by experienced spine surgeons. The operative technique included laminectomy and/or medial facetectomy according to the patient's radiological compression pattern, neurological findings, and symptomatic level. The number of decompressed levels was determined by preoperative imaging and clinical-radiological correlation. Standard perioperative care included antibiotic prophylaxis, thromboembolism prevention according to institutional protocols, postoperative analgesia, and early mobilization. Physiotherapy was initiated during admission and continued after discharge for six weeks according to patient tolerance and surgical stability.

Postoperative assessments were performed at 1 month, 3 months, and 6 months. At each follow-up visit, functional status was assessed using ODI, pain intensity using VAS, and walking ability using self-reported walking distance and timed walking assessment. Complications were recorded as minor or major. Minor complications included superficial wound infection and transient neurological symptoms, whereas major complications included deep infection, dural tear, reoperation, or other serious postoperative adverse events. Length of hospital stay was recorded in days from surgery to discharge.

To reduce measurement bias, outcome assessments were performed using standardized forms by trained research assistants. Baseline clinical variables were cross-checked against hospital records, and functional assessments were performed independently by two assessors where feasible. Discrepancies were resolved through review with the supervising surgeon. Data were entered into Microsoft Excel and screened for missing values, logical inconsistencies, coding errors, and outliers before statistical analysis. Complete-case analysis was used for the final cohort because patients lost to follow-up did not contribute six-month outcome data.

Statistical analysis was performed using SPSS version 28. Continuous variables were summarized as mean and standard deviation or median and interquartile range depending on distribution, while categorical variables were presented as frequencies and percentages. Normality was assessed before selecting parametric or non-parametric tests. Comparisons across frailty categories were performed using chi-square tests for categorical variables, one-way analysis of variance for normally distributed continuous variables, and Kruskal-Wallis tests for non-normally distributed variables. Post hoc pairwise comparisons were interpreted with adjustment for multiple comparisons where applicable.

Multivariate logistic regression was used to evaluate whether preoperative frailty independently predicted poor functional recovery at six months after adjusting for age, sex, body mass index, and comorbidity burden. Results were reported as odds ratios with 95% confidence intervals and p-values. Multicollinearity was assessed using variance inflation factors before final model interpretation. Model discrimination was evaluated using receiver operating characteristic analysis, comparing the predictive performance of frailty score with chronological age alone. Kaplan-Meier analysis was used to compare time to functional recovery across frailty groups, with recovery defined by achievement of the prespecified functional recovery criterion during follow-up, and log-rank testing was used for group comparison. A p-value of less than 0.05 was considered statistically significant.

The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Ethical approval was obtained from the Ethics Review Committees of the participating hospitals before data collection. All participants received information about the study purpose, procedures, potential risks, benefits, confidentiality safeguards, and voluntary participation. Written informed consent was obtained before enrollment, and participants were informed that refusal or withdrawal would not affect their medical care. Data confidentiality was maintained by assigning unique study codes and storing study records in secure, password-protected files.

RESULTS

A total of 170 patients were included in the final analysis after 210 were assessed for eligibility, 180 were enrolled, and 10 were lost to follow-up. The mean age was 68.4 ± 5.6 years, and 92 participants were male. Frailty assessment categorized 60 patients as non-frail, 78 as pre-frail, and 32 as frail. Frailty showed a clear clinical gradient across baseline risk markers, with frail patients being older, having higher rates of hypertension, diabetes, and ASA class ≥3.

Table 1. Baseline Demographic and Clinical Characteristics by Frailty Category

Characteristic	Non-frail (n=60)	Pre-frail (n=78)	Frail (n=32)	Total (n=170)	p-value
Age, years	66.2 ± 4.8	68.5 ± 5.3	72.1 ± 5.7	68.4 ± 5.6	<0.001
Male sex, n (%)	34 (57%)	44 (56%)	14 (44%)	92 (54%)	0.41
BMI, kg/m²	26.8 ± 3.2	27.3 ± 3.5	27.8 ± 3.6	27.1 ± 3.4	0.38

Characteristic	Non-frail (n=60)	Pre-frail (n=78)	Frail (n=32)	Total (n=170)	p-value
Hypertension, n (%)	18 (30%)	29 (37%)	16 (50%)	63 (37%)	0.048
Diabetes mellitus, n (%)	12 (20%)	23 (29%)	14 (44%)	49 (29%)	0.041
ASA class ≥3, n (%)	10 (17%)	22 (28%)	14 (44%)	46 (27%)	0.011
Lumbar stenosis, n (%)	44 (73%)	57 (73%)	18 (56%)	119 (70%)	0.17
Spondylolisthesis, n (%)	16 (27%)	21 (27%)	14 (44%)	51 (30%)	0.17

The mean operative time was 112 ± 22 minutes, and mean blood loss was 210 ± 75 mL. No intraoperative mortality occurred. Postoperative complications increased progressively with frailty severity, from 7% in non-frail patients to 12% in pre-frail patients and 25% in frail patients. Length of hospital stay also increased significantly across frailty categories, indicating greater postoperative resource use among frail patients.

Table 2. Surgical Outcomes and Postoperative Complications by Frailty Category

Outcome	Non-frail (n=60)	Pre-frail (n=78)	Frail (n=32)	p-value
Complications, n (%)	4 (7%)	9 (12%)	8 (25%)	<0.01
Major complications, n (%)				
Hospital stay, days	3.1 ± 0.8	4.2 ± 1.2	5.1 ± 1.5	<0.001
Operative mortality	0	0	0	—

Functional recovery differed substantially by frailty category. At six months, non-frail patients achieved the greatest mean ODI reduction, VAS pain reduction, walking-distance improvement, and proportion of good recovery. Frail patients improved after surgery but had consistently lower functional gains. The between-group gradient was clinically meaningful, with frail patients showing approximately 15.8 fewer ODI recovery points than non-frail patients.

Table 3. Functional Outcomes at Six Months After Lumbar Decompression

Outcome	Non-frail (n=60)	Pre-frail (n=78)	Frail (n=32)	p-value
ODI reduction, points	34.5 ± 8.7	28.1 ± 9.4	18.7 ± 7.9	<0.001
VAS pain reduction, points	5.2 ± 1.4	4.0 ± 1.6	2.7 ± 1.2	<0.001
Walking distance improvement, m	210 ± 45	160 ± 38	110 ± 40	<0.001
Good functional recovery, n (%)	46 (77%)	45 (58%)	11 (34%)	<0.001

Multivariate logistic regression showed that frailty independently predicted poor functional recovery after adjustment for age, sex, BMI, and comorbidity burden.

Table 4. Multivariate Predictors of Poor Functional Recovery at Six Months

Predictor	OR	95% CI	p-value
Frailty score	3.5	1.8–6.8	<0.001
Age, per year	1.1	0.98–1.25	0.12

Chronological age was not a statistically significant predictor after adjustment, supporting the clinical value of frailty assessment beyond age alone. ROC analysis demonstrated stronger discrimination for frailty than age, with AUC values of 0.78 and 0.61, respectively.

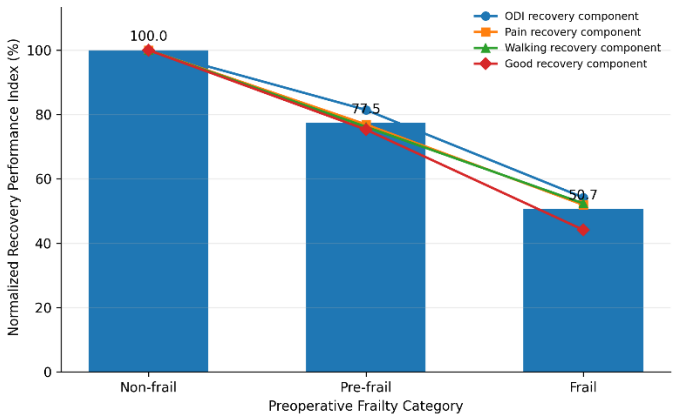

Figure 3. Composite Functional Recovery Gradient Across Frailty

The composite recovery index declined from 100.0% in non-frail patients to 77.5% in pre-frail patients and 50.7% in frail patients, demonstrating a progressive deterioration in multidimensional recovery performance across frailty categories. This gradient integrated ODI reduction, VAS pain improvement, walking-distance gain, and the proportion achieving good recovery, showing that frail patients retained only about half of the recovery performance observed in non-frail patients despite undergoing the same broad surgical intervention. These findings reinforce frailty as a clinically meaningful predictor of postoperative functional limitation rather than merely a marker of complication risk.

DISCUSSION

This prospective cohort study demonstrated that preoperative frailty was strongly associated with postoperative functional recovery, complication burden, and length of hospital stay among elderly patients undergoing lumbar decompression surgery. Although all frailty groups showed postoperative improvement, the magnitude of recovery differed substantially across biological risk strata. Non-frail patients achieved the greatest six-month improvement in disability, pain, walking capacity, and overall recovery classification, whereas frail patients showed slower and more limited improvement despite receiving the same broad surgical intervention. These findings support the central hypothesis that frailty reflects clinically meaningful physiological vulnerability and provides more useful prognostic information than chronological age alone.

The observed reduction in recovery among frail patients is consistent with the broader concept that frailty represents diminished physiological reserve, impaired stress response, sarcopenia, multimorbidity, and reduced rehabilitation tolerance. Earlier frailty models described this vulnerability either as a clinical phenotype or as an accumulation of health deficits, both of which are relevant to older surgical patients (2,3). In the present study, frail patients had higher baseline comorbidity burden, higher ASA class, longer hospitalization, and poorer functional gains, suggesting that frailty influences recovery through both medical and functional pathways. These findings align with surgical literature showing that frailty predicts postoperative complications, institutional discharge, and prolonged recovery more effectively than routine demographic assessment alone (4,5).

The relationship between frailty and adverse outcomes in the present cohort is also consistent with spine surgery evidence. Systematic reviews have shown that frailty is associated with worse outcomes after degenerative spine surgery, including major complications, longer hospital stay, and non-home discharge (6,7). Studies using modified frailty indices in elderly spinal surgery patients have similarly supported frailty as a practical tool for risk stratification (8). The present findings extend this evidence by focusing specifically on functional recovery after lumbar decompression, showing that frailty was not only associated with complications but also with clinically meaningful differences in ODI improvement, pain reduction, walking-distance gain, and likelihood of good recovery.

A key finding was that chronological age was not an independent predictor of poor functional recovery after adjustment, whereas frailty remained statistically significant. This distinction is clinically important because surgical decisions in elderly patients are often influenced heavily by age. Previous lumbar decompression studies have shown that older patients can still experience meaningful postoperative improvement, and age alone does not consistently predict poor outcome (11–13). The present findings reinforce that elderly patients should not be excluded from decompression surgery solely because of age; instead, biological reserve, comorbidity burden, and functional vulnerability should be evaluated systematically before surgery.

The functional recovery gradient observed in this study has direct implications for preoperative counseling. Non-frail patients achieved a 34.5-point ODI reduction and 5.2-point VAS reduction at six months, while frail patients achieved only an 18.7-point ODI reduction and 2.7-point VAS reduction. Similarly, good functional recovery declined from 77% in non-frail patients to 34% in frail patients. These differences are large enough to be clinically meaningful and should be discussed with patients and

families during surgical decision-making. Frail patients may still benefit from surgery, but expectations regarding the speed and extent of recovery should be individualized.

The findings also support incorporation of frailty screening into routine preoperative pathways in tertiary hospitals. In Pakistan, geriatric care services remain limited, and older surgical patients are often assessed through age, comorbidities, and anesthetic risk alone (15,16). A structured frailty assessment may help identify patients requiring prehabilitation, nutritional optimization, closer postoperative monitoring, extended physiotherapy, or more detailed discharge planning. This is especially relevant for frail and pre-frail patients, who may represent a modifiable risk group if identified before surgery.

This study has limitations. Although the sample size was adequate for detecting clinically relevant differences in recovery, larger multicenter cohorts would improve generalizability. The follow-up period was limited to six months, which captures the major early recovery window but does not assess longer-term independence, recurrent symptoms, delayed complications, or quality of life trajectories. Some unmeasured factors, including socioeconomic status, caregiver support, psychological resilience, nutritional status, and adherence to rehabilitation, may also have influenced recovery. Despite these limitations, the prospective design, standardized frailty assessment, repeated postoperative follow-up, and adjustment for major confounders strengthen the clinical relevance of the findings.

CONCLUSION

Preoperative frailty is a strong and clinically meaningful predictor of postoperative functional recovery, complications, and hospital stay among elderly patients undergoing lumbar decompression surgery. Frailty assessed through the Modified Frailty Index provided better prognostic value than chronological age alone, indicating that surgical risk assessment in older adults should move beyond age-based judgment toward biological and functional risk stratification. Incorporating frailty screening into routine preoperative evaluation may improve patient selection, counseling, perioperative optimization, rehabilitation planning, and shared decision-making in tertiary-care spine surgery settings.

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