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Review Article

Outcomes of Posterior Instrumented Lumbar Fusion With or Without Physiotherapy: A Narrative Review

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Abstract

Posterior instrumented lumbar fusion (PILF) is a widely performed surgical intervention for treating degenerative lumbar disorders. Although modern instrumentation achieves high fusion rates, many patients experience residual pain and disability. Physiotherapy is often prescribed to optimize recovery; however, its effectiveness, timing, and format remain debatable. A narrative review was conducted by searching PubMed and Embase (2019–2025) for systematic reviews, randomized controlled trials, and meta-analyses reporting the outcomes of PILF with or without rehabilitation. The outcomes included pain, disability, quality of life, fear-avoidance, return to work, and fusion success. Structured physiotherapy programs, especially multimodal interventions combining exercise and cognitive-behavioral strategies, were associated with improved pain, disability, and psychosocial recovery compared with the usual care. Early initiation of physiotherapy within one month was safe and accelerated short-term outcomes, although long-term differences diminished after one year. Posterior instrumentation consistently achieves high fusion rates and favorable surgical outcomes; however, evidence on whether rehabilitation influences structural outcomes, such as hardware survival or adjacent segment degeneration, is limited. Physiotherapy provides meaningful additive benefits after PILF, particularly in the first 6 months. Therefore, incorporating structured rehabilitation into postoperative care is recommended. Future trials should standardize protocols, assess cost-effectiveness, and explore long-term outcomes.

Keywords: *Cognitive-behavioral therapy, Degenerative spinal disorders, Enhanced Recovery After Surgery, Rehabilitation, Return to work*

Introduction

Low back pain is a leading cause of disability worldwide. Degenerative lumbar disorders, such as spondylolisthesis, disc degeneration, and spinal stenosis, are major contributors to the global disease burden. When conservative treatments fail, surgery is the only option. Posterior instrumented lumbar fusion (PILF) has been largely successful in managing the surgical cause of spinal stabilization, relieving pain, and treating the functional aspect of the problem. Surgical developments in pedicle screw fixation, posterior lumbar interbody fusion (PLIF), and transforaminal lumbar interbody fusion (TLIF) have made it possible to achieve better stability and fusion rates, and in most cases, radiological success is more than 90% (1–3).

However, clinical outcomes do not always improve significantly despite these technical successes. Moreover, a third or even 40% of patients still experience considerable pain and functional limitations after meeting the criteria for solid fusion (4). The gap between radiological and clinical success signifies the complex nature of the recovery process. Postoperative results that go beyond structural stabilization are influenced by the condition of the muscles, the inability of neuromotor control, psychological issues such as fear of pain and catastrophizing, and the occurrence of adjacent segment degeneration (5).

Physiotherapy is one of the recommended adjuncts that has been suggested to help overcome these obstacles. It involves the rehabilitation of spinal mobility, construction of the strength of paraspinal muscles, relearning motor control, and addressing psychological contributors to disability. However, the rehabilitation after spinal fusion has been a source of controversy for many years. Questions regarding the true efficacy of therapy, correct timing of initiation, and most effective therapeutic strategy combinations remain unanswered. Earlier reviews had conflicting results regarding the efficacy of rehabilitation after spinal fusion, but during the last five years, there has been a marked increase in high-quality randomized trials and systematic reviews that have provided more definitive evidence (4,5).

This narrative review summarizes recent studies on postoperative outcomes after posterior instrumented lumbar fusion with and without physiotherapy. The main purpose of this review is to examine the currently available evidence, highlight the clinical and structural effects of rehabilitation, and identify areas that require further investigation to improve postoperative care.

Methods

This study was designed as a narrative review was conducted to integrate recent evidence on the outcomes of post-operative physiotherapy in patients who underwent posterior instrumented lumbar fusion. To identify relevant studies published between January 2019 and August 2025, a literature search was performed in PubMed and Embase.

The search strategy included the following keywords: lumbar spinal fusion, posterior instrumentation, rehabilitation, physiotherapy, exercise, and degenerative diseases. The eligible studies were systematic reviews, randomized controlled trials, and meta-analyses that studied adult patients who underwent posterior instrumented lumbar fusion and reported outcomes such as pain, disability, quality of life, fear-avoidance, return to work, or fusion success. Only articles written in English were considered. The titles and abstracts were screened to evaluate eligibility, and the full texts were accessed if necessary. Owing to differences in surgical approaches, rehabilitation protocols, and outcome measures among the studies, the data were synthesized narratively.

Results

Bogaert et al. (4) pooled 18 randomized trials with >1,400 patients, which demonstrated that rehabilitation significantly reduced the level of disability and pain, increased return-to-work rates, and reduced fear-avoidance. Özden et al. (1) concluded that a multimodal approach to rehabilitation that integrates exercise and cognitive-behavioral therapy results in more profound benefits than just exercise even after a long period of time. In a similar vein, Kim et al. (5) echoed that multimodal programs were more effective in achieving pain, function, and psychological outcomes than routine advice alone. Timeline of rehabilitation benefits comparing early versus delayed physiotherapy after lumbar fusion showed in (Fig. 1)

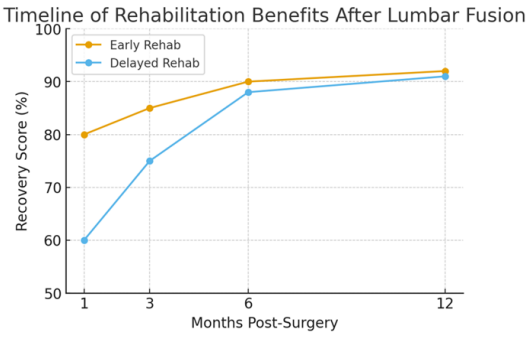


Figure 1. Timeline of Rehabilitation Benefits Comparing Early versus Delayed Physiotherapy After Lumbar Fusion.

Enhanced Recovery After Surgery (ERAS) protocols (6) have been known to visibly exhibit their advantageous effects in posterior lumbar fusion as well. A South Korean cohort study done in 2024 on 88 patients undergoing one- or two-level fusion has revealed that the patients managed under ERAS care had a significantly lower opioid and antiemetic medication consumption, better leg pain at six months, higher functional recovery as measured by ODI and EQ-5D scores, and lower incidence of complications, while the fusion rate was similar to that of the standard care group.

Posterior instrumentation techniques are sometimes very successful in yielding positive results. Miyashita et al. (7) showed that percutaneous pedicle screw systems resulted in a five-year improvement in pain and function, in addition to a 90% fusion rate. An overview of such comparative studies claims that the method of fixation has the greatest impact. A systematic review and meta-analysis that comprised 14 studies with more than 900 patients compared lateral lumbar interbody fusion (LLIF) with the use of instruments and stand-alone for degenerative lumbar disease. According to the authors, instrumented LLIF reached higher fusion rates, larger spinal stability, and lower occurrences of cage subsidence in comparison with stand-alone procedures. Moreover, clinical outcomes like alleviation of pain and rehabilitation of disability were better in the group with instruments, which means that there is an additional benefit of posterior fixation in both structural and functional outcomes.

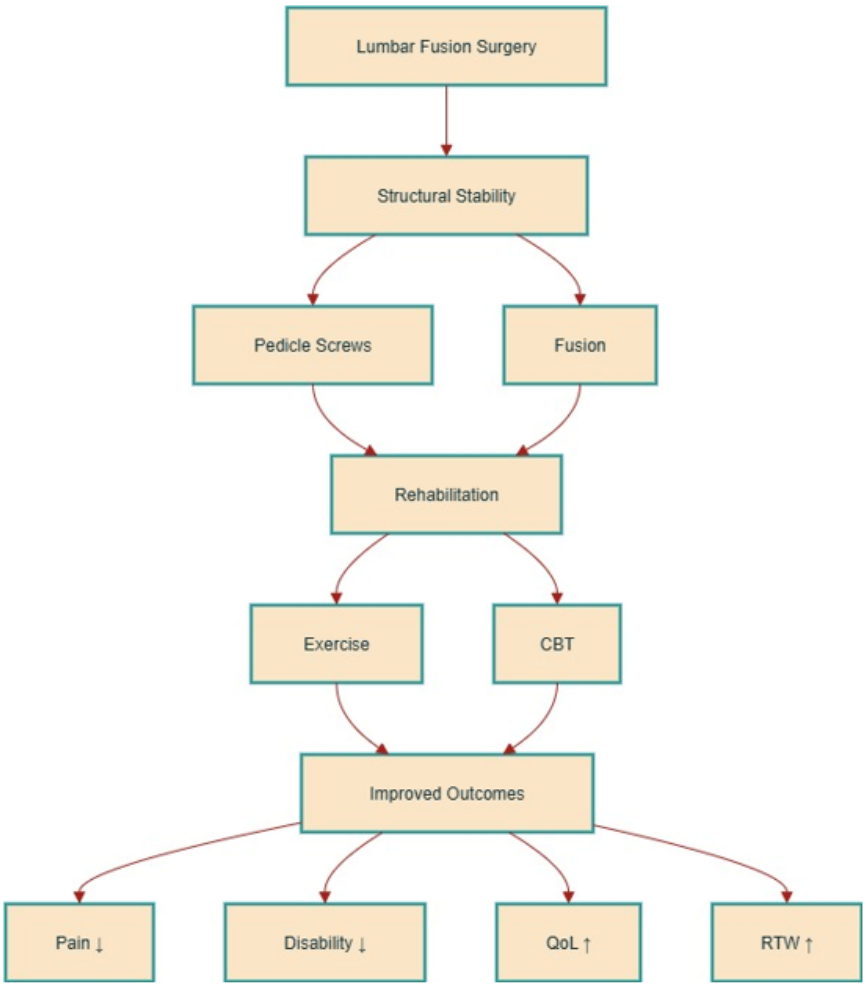
Kou et al. (8) recently evaluated the effectiveness and safety of lateral lumbar interbody fusion (LLIF) with the aid of or without the auxiliary posterior fixation. The assessment revealed that compared to stand-alone LLIF, LLIF combined with posterior fixation yielded improvements in the stability of the fusion, less cage subsidence, and better spinal alignment preservation. Also, clinical outcomes such as pain alleviation and functional improvement were more favorable in the instrumented groups, although the rate of complications was similar across the two approaches. The results presented here indicate that the use of posterior fixation should be considered in those patients with a higher risk of mechanical failure and instability.

Evidence summary of rehabilitation after lumbar spinal fusion mentioned in (Table 1).

Table 1. Evidence Summary of Rehabilitation After Lumbar Spinal Fusion.

Author (Year)	Study Design	Sample Size	Key Findings
Bogaert 2022	Systematic review	18 RCTs (~1,400)	Rehabilitation reduced pain and disability, improved return to work
Özden 2022	Systematic Review & Meta-Analysis	11 RCTs	Exercise plus cognitive-behavioral therapy is superior to exercise alone
Kim 2023	Meta-analysis	10 trials	Multimodal rehabilitation is associated with better outcomes
Ji Uk Choi 2024	Prospective cohort (pre-ERAS vs post-ERAS)	88 patients (41 pre-ERAS, 47 post-ERAS)	ERAS significantly reduced opioid and antiemetic use, improved leg pain at 6 months, enhanced functional outcomes, and lowered complication rates; fusion rates remained comparable between groups.
Tomohiro 2022	Prospective study	115 patients	90% fusion achieved; sustained results at 5 years
Jiang 2024	Systematic review & meta-analysis	14 studies, >900 patients	Instrumented LLIF demonstrated higher fusion rates, greater spinal stability, and lower subsidence rates compared with stand-alone LLIF. Clinical outcomes (pain and disability scores) were also superior in the instrumented group.

a) ERAS = Enhanced Recovery After Surgery, b) RCT = randomized controlled trial,



a) CBT = cognitive behavioral therapy; b) QoL = quality of life; c) RTW = return to work

Figure 2. Conceptual flowchart of recovery following posterior instrumented lumbar fusion with or without physiotherapy.

Discussion

This narrative review illustrates that postoperative outcomes after posterior instrumented lumbar fusion (PILF) depend not only on radiographic fusion success but also on the quality of postoperative functional recovery. In fact, contemporary literature shows that a significant percentage of patients still experience pain and disability even after technically successful fusion, pointing to the complex nature of postoperative outcomes (9–11).

Various studies in recent years support that structured postoperative physiotherapy—especially supervised and multimodal rehabilitation—can lead to better pain management, less disability, improved functional capacity, and quicker return to everyday activities than minimal or unsupervised care (12–16). The most significant effects are seen in the early postoperative phase. However, long-term changes beyond one or two years are less clear.

Psychologically informed rehabilitation further amplifies therapy effectiveness by addressing fear-avoidant behavior and maladaptive pain beliefs, both of which are known to predict continuous disability after spine surgery (17–20). Meanwhile, Enhanced Recovery After Surgery (ERAS) programs, which include early mobilization and coordinated rehabilitation, have been proven to enhance short-term recovery, reduce opioid use, and shorten hospital stays without increasing the risk of surgery (21–23).

Mechanistic Implications

Postoperative rehabilitation benefits following PILF are likely due to the combined biomechanical, neuromuscular, and psychosocial effects. The use of posterior instrumentation stabilizes the segment immediately and limits pathological micromotion. The biomechanical environment is good for early functional loading (24–26). This mechanical stability may make it easier for a patient to undergo rehabilitation indirectly by reducing pain that is due to mechanical instability and, therefore, allowing safer movement.

Furthermore, exercise-based physiotherapy helps in postoperative recovery by strengthening core muscles, improving neuromuscular coordination, proprioception, and endurance (13–15). At the same time, cognitive-behavioral therapy helps in managing central pain processing mechanisms, fear-avoidance, and catastrophizing—these are some of the factors known to increase pain perception and restrict functional recovery even in the absence of any structural problem (17–19).

On top of that, ERAS protocols support the patient's recovery by lessening the body's stress response to surgery, providing optimal pain control, and encouraging early walking. Altogether, these aspects help patients reach functional independence more quickly and improve short-term outcomes. However, they do not necessarily lead to changes in fusion biology or long-term structural markers (21–23).

Strengths and Limitations

The major merit of the current literature is the growing number of prospective trials, systematic reviews, and protocol-driven cohort studies that focus on rehabilitation and perioperative care after lumbar fusion. These research efforts shed light on this understudied area of recovery, besides mere radiographic outcomes (27).

Nevertheless, some issues remain unresolved. Rehabilitation programs are still very diverse in terms of when they are started, how long they last, level of supervision, and the choice of therapeutic components, which makes it difficult to compare results and reach an agreement on the best practice (13–16). Moreover, data are scarce for very long-term outcomes beyond 2 to 5 years, especially for anatomical changes such as adjacent segment degeneration, implant longevity, and the sustainability of functional improvements (28).

Most ERAS and rehabilitation trials are non-interventional studies, thus associated with potential consumer selection bias and possible non-adherence to protocols (21,23). Furthermore, variables related to the patients, such as initial degree of disability, bone density, presence of other diseases, and psychosocial risk factors, have been unevenly considered in the studies' outcome measures, opening up some limitations for an individualized interpretation of the findings.

Clinical Translation Potential

The outcome of this review is in favor of a move to integrated, multidisciplinary postoperative care pathways following PILF. Structured physiotherapy, especially supervised ones with a multimodal approach, should be regarded as a necessary component of post-surgery recovery management rather than an optional extra, particularly during the early recovery phase.

Starting the rehabilitation process early, if clinically safe, can help patients recover faster at least in the short-term. Using a psychological approach in combination with suitable interventions may also significantly improve the success rate of treatment in patients whose recovery is delayed because of fear-avoidant or catastrophizing behaviors (17–20). ERAS-guided pathways are a good tool to ensure consistency in perioperative care, minimize unnecessary reliance on opioids, and generally raise the efficiency of the system without compromising patient outcomes (21–23) .

Patient-specific risk stratification and standardized rehabilitation protocols adjusted to surgical complexity and functional capacity should be the focus of future clinical implementation. To improve these pathways and justify their widespread use in different healthcare systems, high-quality randomized trials with long-term follow-up and cost-effectiveness analyses are necessary (29,30). Conceptual flowchart of recovery following posterior instrumented lumbar fusion with or without physiotherapy is shown in (Figure 2)

Conclusion

Posterior instrumented lumbar fusion provides reliable mechanical stability and high fusion rates, yet functional disability may persist in many patients. Structured postoperative physiotherapy, particularly multimodal programs, improves short-term functional and psychosocial outcomes and supports earlier return to work, although long-term benefits remain uncertain.

Authors' Contributions

SJ participated in the design of the study, contributed to data collection and data reduction/analysis; HM, FM participated in the design of the study; AR participated in the design of the study and contributed to data collection; MS contributed to data reduction/analysis; AS contributed to data analysis and interpretation of results; FS contributed to manuscript writing, formatting and submitted to the journal.

All authors have read and approved the final version of the manuscript and agree with the order of presentation of the authors.

Conflict of Interest

There are no financial conflicts of interest to disclose.

References

1. Özden F. The Effectiveness of Physical Exercise After Lumbar Fusion Surgery: A Systematic Review and Meta-Analysis. World Neurosurg [Internet]. 2022 Jul 1 [cited 2025 Oct 2];163:e396–412. Available from: https://pubmed.ncbi.nlm.nih.gov/35398574/

2. Jiang L, Liu L, Dong L, Xu Z, Zhang X, Qian L. Comparison of instrumented and stand-alone lateral lumbar interbody fusion for lumbar degenerative disease: a systematic review and meta-analysis. BMC Musculoskelet Disord [Internet]. 2024 Dec 1 [cited 2025 Oct 2];25(1). Available from: https://pubmed.ncbi.nlm.nih.gov/38310205/

3. Kou N, Zhang R, Liu F, Zhou H, Ren L. Efficacy and safety of lateral lumbar interbody fusion for lumbar degenerative diseases with or without auxiliary posterior fixation: a meta-analysis and systematic review. BMC Musculoskelet Disord [Internet]. 2025 Dec 1 [cited 2025 Oct 2];26(1):1–11. Available from: https://bmcmusculoskeletdisord.biomedcentral.com/articles/10.1186/s12891-024-08094-6

4. Bogaert L, Thys T, Depreitere B, Dankaerts W, Amerijckx C, Van Wambeke P, et al. Rehabilitation to improve outcomes of lumbar fusion surgery: a systematic review with meta-analysis. Eur Spine J [Internet]. 2022 Jun 1 [cited 2025 Oct 2];31(6):1525–45. Available from: https://pubmed.ncbi.nlm.nih.gov/35258644/

5. Kim KS, An J, Kim JO, Lee MY, Lee BH. Effects of Pain Neuroscience Education Combined with Lumbar Stabilization Exercise on Strength and Pain in Patients with Chronic Low Back Pain: Randomized Controlled Trial. J Pers Med [Internet]. 2022 Feb 1 [cited 2025 Oct 2];12(2). Available from: https://pubmed.ncbi.nlm.nih.gov/35207790/

6. Choi JU;, Kee TH;, Lee DH;, Hwang CJ;, Park S;, Cho JH, et al. Enhanced Recovery After Surgery Protocols in One- or Two-Level Posterior Lumbar Fusion: Improving Postoperative Outcomes. Journal of Clinical Medicine 2024, Vol 13, Page 6285 [Internet]. 2024 Oct 21 [cited 2025 Oct 2];13(20):6285. Available from: https://www.mdpi.com/2077-0383/13/20/6285/htm

7. Miyashita T, Ataka H, Kato K, Tanno T. Good 5-year postoperative outcomes after facet fusion using a percutaneous pedicle screw system for degenerative lumbar spondylolisthesis. Neurosurg Rev [Internet]. 2022 Jun 1 [cited 2025 Oct 2];45(3):2269–76. Available from: https://pubmed.ncbi.nlm.nih.gov/35099669/

8. Kou N, Zhang R, Liu F, Zhou H, Ren L. Efficacy and safety of lateral lumbar interbody fusion for lumbar degenerative diseases with or without auxiliary posterior fixation: a meta-analysis and systematic review. BMC Musculoskelet Disord [Internet]. 2025 Dec 1 [cited 2025 Oct 2];26(1):1–11. Available from: https://bmcmusculoskeletdisord.biomedcentral.com/articles/10.1186/s12891-024-08094-6

9. Mannion AF, Brox JI, Fairbank JC. Consensus at last! Long-term results of all randomized controlled trials show that fusion is no better than non-operative care in improving pain and disability in chronic low back pain. Spine Journal [Internet]. 2016 May 1 [cited 2026 Jan 29];16(5):588–90. Available from: https://pubmed.ncbi.nlm.nih.gov/27261844/

10. Parker SL, Mendenhall SK, Godil SS, Sivasubramanian P, Cahill K, Ziewacz J, et al. Incidence of Low Back Pain After Lumbar Discectomy for Herniated Disc and Its Effect on Patient-reported Outcomes. Clin Orthop Relat Res [Internet]. 2015 Jun 1 [cited 2026 Jan 29];473(6):1988–99. Available from: https://pubmed.ncbi.nlm.nih.gov/25694267/

11. Carragee EJ, Cheng I. Minimum acceptable outcomes after lumbar spinal fusion. Spine Journal [Internet]. 2010 Apr [cited 2026 Jan 29];10(4):313–20. Available from: https://pubmed.ncbi.nlm.nih.gov/20362247/

12. Nielsen PR, Jørgensen LD, Dahl B, Pedersen T, Tønnesen H. Prehabilitation and early rehabilitation after spinal surgery: randomized clinical trial. Clin Rehabil [Internet]. 2010 Feb [cited 2026 Jan 29];24(2):137–48. Available from: https://pubmed.ncbi.nlm.nih.gov/20103575/

13. Abbott AD, Tyni-Lenné R, Hedlund R. Early rehabilitation targeting cognition, behavior, and motor function after lumbar fusion: a randomized controlled trial. Spine (Phila Pa 1976) [Internet]. 2010 Apr [cited 2026 Jan 29];35(8):848–57. Available from: https://pubmed.ncbi.nlm.nih.gov/20354468/

14. Christensen FB, Laurberg I, Bünger CE. Importance of the Back-Café Concept to Rehabilitation after Lumbar Spinal Fusion: A Randomized Clinical Study with a 2-Year Follow-Up. Spine (Phila Pa 1976). 2003 Dec 1;28(23):2561–9. Available from: https://pubmed.ncbi.nlm.nih.gov/14652472/

15. Oestergaard LG, Nielsen C V., Bünger CE, Sogaard R, Fruensgaard S, Helmig P, et al. The effect of early initiation of rehabilitation after lumbar spinal fusion: a randomized clinical study. Spine (Phila Pa 1976) [Internet]. 2012 Oct 1 [cited 2026 Jan 29];37(21):1803–9. Available from: https://pubmed.ncbi.nlm.nih.gov/22565381/

16. McGregor AH, Probyn K, Cro S, Doré CJ, Burton AK, Balagué F, et al. Rehabilitation following surgery for lumbar spinal stenosis. A Cochrane review. Spine (Phila Pa 1976) [Internet]. 2014 Jun 19 [cited 2026 Jan 29];39(13):1044–54. Available from: https://pubmed.ncbi.nlm.nih.gov/24732858/

17. Archer KR, Devin CJ, Vanston SW, Koyama T, Phillips SE, George SZ, et al. Cognitive-Behavioral-Based Physical Therapy for Patients With Chronic Pain Undergoing Lumbar Spine Surgery: A Randomized Controlled Trial. J Pain [Internet]. 2016 Jan 1 [cited 2026 Jan 29];17(1):76–89. Available from: https://pubmed.ncbi.nlm.nih.gov/26476267/

18. Wilhelm M, Reiman M, Goode A, Richardson W, Brown C, Vaughn D, et al. Psychological Predictors of Outcomes with Lumbar Spinal Fusion: A Systematic Literature Review. Physiother Res Int [Internet]. 2017 Apr 1 [cited 2026 Jan 29];22(2). Available from: https://pubmed.ncbi.nlm.nih.gov/26270324/

19. Ostelo RWJG, De Vet HCW, Berfelo MW, Kerckhoffs MR, Vlaeyen JWS, Wolters PMJC, et al. Effectiveness of behavioral graded activity after first-time lumbar disc surgery: short term results of a randomized controlled trial. Eur Spine J [Internet]. 2003 Dec [cited 2026 Jan 29];12(6):637–44. Available from: https://pubmed.ncbi.nlm.nih.gov/14505118/

20. Vlaeyen JWS, Linton SJ. Fear-avoidance model of chronic musculoskeletal pain: 12 years on. Pain [Internet]. 2012 Jun [cited 2026 Jan 29];153(6):1144–7. Available from: https://pubmed.ncbi.nlm.nih.gov/22321917/

21. Wang MY, Chang PY, Grossman J. Development of an Enhanced Recovery After Surgery (ERAS) approach for lumbar spinal fusion. J Neurosurg Spine [Internet]. 2017 Apr 1 [cited 2026 Jan 29];26(4):411–8. Available from: https://pubmed.ncbi.nlm.nih.gov/28009223/

22. Dietz N, Sharma M, Adams S, Alhourani A, Ugiliweneza B, Wang D, et al. Enhanced Recovery After Surgery (ERAS) for Spine Surgery: A Systematic Review. World Neurosurg [Internet]. 2019 Oct 1 [cited 2026 Jan 29];130:415–26. Available from: https://pubmed.ncbi.nlm.nih.gov/31276851/

23. Elsarrag M, Soldozy S, Patel P, Norat P, Sokolowski JD, Park MS, et al. Enhanced recovery after spine surgery: a systematic review. Neurosurg Focus [Internet]. 2019 Apr 1 [cited 2026 Jan 29];46(4). Available from: https://pubmed.ncbi.nlm.nih.gov/30933920/

24. Rohlmann A, Zander T, Rao M, Bergmann G. Applying a follower load delivers realistic results for simulating standing. J Biomech [Internet]. 2009 Jul 22 [cited 2026 Jan 29];42(10):1520–6. Available from: https://pubmed.ncbi.nlm.nih.gov/19433325/

25. Ghezelbash F, Schmidt H, Shirazi-Adl A, El-Rich M. Internal load-sharing in the human passive lumbar spine: Review of in vitro and finite element model studies. J Biomech [Internet]. 2020 Mar 26 [cited 2026 Jan 29];102. Available from: https://pubmed.ncbi.nlm.nih.gov/31759622/

26. Yu Q, Zou ZL, Lu HG, Pan XK, Hu XQ, Shen ZH. Finite element analysis of biomechanical investigation on diverse internal fixation techniques in oblique lumbar interbody fusion. BMC Musculoskelet Disord [Internet]. 2024 Dec 1 [cited 2026 Jan 29];25(1):804. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC11470635/

27. Glassman SD, Carreon LY, Djurasovic M, Dimar JR, Johnson JR, Puno RM, et al. Lumbar fusion outcomes stratified by specific diagnostic indication. Spine J [Internet]. 2009 Jan [cited 2026 Jan 29];9(1):13–21. Available from: https://pubmed.ncbi.nlm.nih.gov/18805059/

28. Lehmann TR, Spratt KF, Tozzi JE, Weinstein JN, Reinarz SJ, El-Khoury GY, et al. Long-term follow-up of lower lumbar fusion patients. Spine (Phila Pa 1976) [Internet]. 1987 [cited 2026 Jan 29];12(2):97–104. Available from: https://pubmed.ncbi.nlm.nih.gov/2954220/

29. Deyo RA, Nachemson A, Mirza SK. Spinal-fusion surgery - the case for restraint. N Engl J Med [Internet]. 2004 Feb 12 [cited 2026 Jan 29];350(7):722–6. Available from: https://pubmed.ncbi.nlm.nih.gov/14960750/

30. Alvin MD, Miller JA, Lubelski D, Rosenbaum BP, Abdullah KG, Whitmore RG, et al. Variations in cost calculations in spine surgery cost-effectiveness research. Neurosurg Focus [Internet]. 2014 [cited 2026 Jan 29];36(6). Available from: https://pubmed.ncbi.nlm.nih.gov/24881633/