Effect Of Body Mass Index (BMI) And Cervical Lordosis in Neurological Recovery After Anterior Cervical Decompression and Fusion for Cervical Spondylotic Myelopathy

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ABSTRACT
Cervical Spondylotic Myelopathy (CSM) is a leading cause of spinal cord dysfunction, often managed with Anterior Cervical Decompression and Fusion (ACDF). While ACDF is effective, the influence of Body Mass Index (BMI) and Cervical Lordosis on neurological recovery remains uncertain. This study evaluates the impact of these factors on postoperative outcomes. A prospective observational study was conducted at NRS Medical College from January 2023 to June 2024, including 74 patients undergoing ACDF for CSM. BMI was categorized as obese(BMI≥30) and non-obese(BMI<30), and cervical lordosis was measured using a C2–C7 Cobb angle. Loss of cervical lordosis was categorized as absent(c2-c7 Cobb's angle > 20 degrees) and present(c2-c7 Cobb's angle<20 degrees). Neurological recovery was assessed using modified Japanese Orthopaedic Association (m-JOA) scores at baseline, 6 weeks, 3 months, and 6 months postoperatively. Statistical analyses included correlation and regression tests, with $p< 0.05$ considered significant. BMI showed no significant correlation with postoperative m-JOA score improvement ($p = 0.793$), suggesting BMI alone is not a predictor of neurological recovery. Cervical lordosis positively correlated with preoperative neurological function ($r = 0.502$, $p = 0.000$) but did not significantly influence postoperative outcomes ($p = 0.824$). ACDF effectively improves neurological function regardless of BMI and cervical alignment. These findings suggest that BMI should not be a contraindication for ACDF, and preoperative cervical lordosis does not strongly predict recovery. Further long-term, multi-center studies are needed to confirm these findings.

Introduction

One of the most frequent causes of spinal cord dysfunction in adults is Cervical Spondylotic Myelopathy (CSM), which is brought on by aging, recurrent mechanical stimulation, and genetic predispositions [1]. It is a progressive motor, sensory, and gait disturbance and a progressive neurological disorder characterized by a decline in functional independence and quality of life [2]. Anterior Cervical Decompression and Fusion (ACDF) is the most commonly performed surgical procedure to treat a patient with CSM [3]. The goal of ACDF is to decompress, stabilize, and fuse the affected cervical spine segment to prevent further neurological deterioration [4]. However patient outcomes following ACDF vary greatly among patients, so research has begun to look into the impact of such patient-specific factors as Body Mass Index (BMI) and Cervical Lordosis on ACDF success rates [5]. There is disagreement concerning the impact of BMI and cervical curvature on neurological recovery following ACDF, despite a large body of research on surgical methods and perioperative care [6].

Numerous research has examined the connection between BMI and the outcomes of ACDF surgery, with varying degrees of agreement. Other studies have emphasized that higher BMI is linked with a higher incidence of surgical complications like wound infection, increased operative time, increased blood loss, and prolonged length of stay in hospital [7,8]. Cases with higher BMI have more epidural fat deposition, which can diminish the spinal decompression effect and lead to the delay of postoperative neurological improvement [9].

Additionally, the fusion rates and rate of requiring revision surgery for pseudoarthrosis in obese patients have been reported to be lower [10]. In a recent study by Zhang et al. (2020), no significant difference in neurological

improvement, fusion rates, or complication rates was found between obese and non-obese patients, thus, BMI alone should not be a contraindication for ACDF surgery [11]. A study emphasised that BMI did not affect cervical sagittal alignment restoration postoperatively, and neurological improvement-modified Japanese Orthopaedic Association (m-JOA) score was similar across different BMI categories [12].

Postoperative neurological recovery following ACDF has been suggested to be affected by cervical lordosis, an important physiological curvature of the cervical spine [13]. Preoperative loss of cervical lordosis is proposed by some studies to cause more mechanical stress on the adjacent spinal segment, which could lead to adjacent segment degeneration (ASD) and worsened neurological recovery after surgery [5]. Thus, while Fehlings et al. (2017) report no association between preoperative cervical alignment and postoperative neurological improvement, other factors such as cord signal changes on MRI, surgical technique, and rehabilitation strategies, may have a greater impact [14]. Another study by McKeon et al. (2024) also demonstrated that cervical sagittal alignment alone does not predict ACDF outcomes, and therefore, long-term studies are needed to fully assess the effect of cervical sagittal alignment on neurological recovery [15].

Previous studies have assessed the relationship between BMI and cervical lordosis and ACDF outcomes; however, the methodologies, follow-up durations, and patient populations in the studies examined have been mixed [16]. Numerous studies pay close attention to the perioperative complication rates and fusion rates but not to neurological recovery metrics like m-JOA scores or functional measures. Moreover, few studies have examined the combined role of BMI and cervical lordosis in ACDF outcomes with no assessment of whether the two variables interact to influence recovery [17]. Further research is warranted to elucidate the actual prognostic value of BMI and cervical curvature in ACDF patients, given the high prevalence of obesity and relative importance attributed to spinal alignment in the planning of surgical treatment.

The purpose of this study is to ascertain how Cervical Lordosis and Body Mass Index (BMI) affect neurological recovery after ACDF for CSM. The study will use m-JOA score analysis of postoperative recovery trends to determine if BMI and cervical lordosis have a significant effect on neurological improvement. The findings will be used to inform the evidence-based clinical decision-making for ACDF for CSM to optimize surgical planning, patient selection, and postoperative care strategies.

Materials and Methods

Study Design

This was an institution-based prospective observational study carried out at the Department of Neurosurgery, NRS Medical College and Hospital, Kolkata. The study was done over 18 months from January 2023 to June 2024 about patient selection, data collection, surgical intervention, postoperative assessments, and statistical analysis.

Patient Selection

Anterior Cervical Decompression and Fusion (ACDF) patients with Cervical Spondylotic Myelopathy (CSM) who were scheduled at the neurosurgery department of NRS Medical College and Hospital were the subjects of the study. Prospective recruiting of eligible patients based on predefined inclusion and exclusion criteria was carried out to minimize the heterogeneity of the study sample.

Inclusion Criteria

Individuals who were 18 years of age or older who had a confirmed diagnosis of CSM based on radiological and clinical evidence were deemed eligible for inclusion. The study also included only those patients who were scheduled for ACDF surgery as part of their treatment plan. Willingness to participate in postoperative follow-up assessments at predetermined time intervals, further adding to the consistency in and reliability of the data collection along the length of the study, were other essential inclusion criteria.

Exclusion Criteria

The study excluded patients who were considered unfit for surgical intervention because of underlying medical comorbidities or contraindications. Finally, individuals who had a history of prior spinal surgery or traumatic myelopathy were not included since these conditions could introduce variability in surgical outcomes and also might confuse the analyzed results regarding neurological recovery following ACDF.

Data Collection

Data collection included the clinical and radiological assessment pre and postoperatively at designated postoperative follow-up intervals. Clinical parameters included Body Mass Index (BMI), and patients were

classified as obese (BMI ≥ 30 kg/m²) according to WHO classification. The modified Japanese Orthopaedic Association (m-JOA) score was used to assess neurological function, which measures upper limb motor function, lower limb motor function, sensory deficits, and sphincter dysfunction, and higher scores indicate better neurological status. Cervical lordosis measurement (C2–C7 Cobb angle) on lateral cervical spine radiographs and Magnetic Resonance Imaging (MRI) evaluations preoperatively of spinal cord compression, intramedullary signal changes, and the presence of ossification of the posterior longitudinal ligament (OPLL) were radiological parameters. The angle between the lower plate of C2 and the lower plate of C7 was measured as C2-C7 Cobb's angle. This angle less than 20 degrees was regarded as 'Loss of cervical lordosis'.The Range of Motion(ROM) indicates the stability of the spine. Instability is measured from neutral, flexion, and extension lateral radiograms. Instability is defined as more than 3.5mm horizontal displacement of one vertebra in relation to an adjacent vertebra. The m-JOA score was used to assess postoperative neurological recovery at baseline (preoperative), 6 weeks, 3 months, and 6 months postoperatively, and also was regarded as surgical outcomes related to preoperative BMI and cervical lordosis, to determine how much recovery was influenced. The total score of mJOA is 18(the lower the score, the more severe the deficits; Normal function score 18; Grade1:15-17 mild myelopathy, Grade2:12-14 moderate myelopathy, Grade3 ≤11 severe myelopathy).

Modified Japanese Orthopaedic Association (mJOA) Score	
CATEGORY	**SCORE**
MOTOR DYSFUNCTION	
Upper extremities	
Unable to move hands	0
Unable to eat with a spoon, but able to move hands	1
Unable to button shirt, but able to eat with a spoon	2
Able to button shirt with great difficulty	3
Able to button shirt with slight difficulty	4
No dysfunction	5
Lower extremities	
Complete loss of motor and sensory function	0
Sensory preservation without the ability to move legs	1
Able to move legs, but unable to walk	2
Able to walk on a flat floor with a walking aid	3
Able to walk up and/or downstairs with handrail	4
Moderate to significant lack of stability, but able to walk up	5
and/or downstairs without handrail	
Mild lack of stability, but able to walk unaided with	6
smooth reciprocation	
No dysfunction	7
SENSORY DYSFUNCTION	
Complete loss of hand sensation	0
Severe sensory loss of pain.	1
Mild sensory loss	2
No sensory loss	3
SPHINCTER DYSFUNCTION	
Unable to void (complete retention)	0
Marked difficulty in micturition (hesitancy)	1
Mild difficulty in micturition (frequency)	2
Normal micturition	3

Statistical Analysis

Descriptive statistics were used to summarize baseline characteristics such as age, sex, BMI distribution, and preoperative clinical scores for all collected data with SPSS (Version 22.0). The relationship between BMI, cervical lordosis, and neurological recovery was evaluated using regression and correlation analysis. While the categorical variables (OPLL existence, BMI class) were displayed as frequencies and percentages, the m-JOA scores, cervical lordosis, and BMI were represented as mean, median, and standard deviation (SD) together with range. Unpaired t-tests, Mann-Whitney U tests, and Pearson or Spearman correlation coefficients were used for statistical comparisons, where data was normal or not, respectively. To find independent variables for postoperative neurological recovery with $p < 0.05$ of statistical significance, the results were analyzed using multiple linear regression analysis.

Ethical Considerations

The study was conducted by the ethical principles of the Declaration of Helsinki and was approved by the Institutional Ethics Committee (IEC) of NRS Medical College and Hospital. All participants provided informed consent after being thoroughly explained the study objectives, potential risks, and benefits. All the collected data were anonymized and kept private, and data access was restricted only to authorized personnel.

Results

Demographic and Clinical Profile

The study had 74 individuals in total (27.0% female, 73.0% male). Table 1 shows the age distribution, which revealed that the age groups with the highest number of patients were those aged 41-50 years (24.3%) and 61-70 years (23.0%).

Table 1: Distribution of participants according to Age group (n=74)

Age Group (years)	Frequency	Percentage (%)
≤20	1	1.4
21-30	5	6.8
31-40	14	18.9
41-50	18	24.3
51-60	15	20.3
61-70	17	23.0
≥71	4	5.4

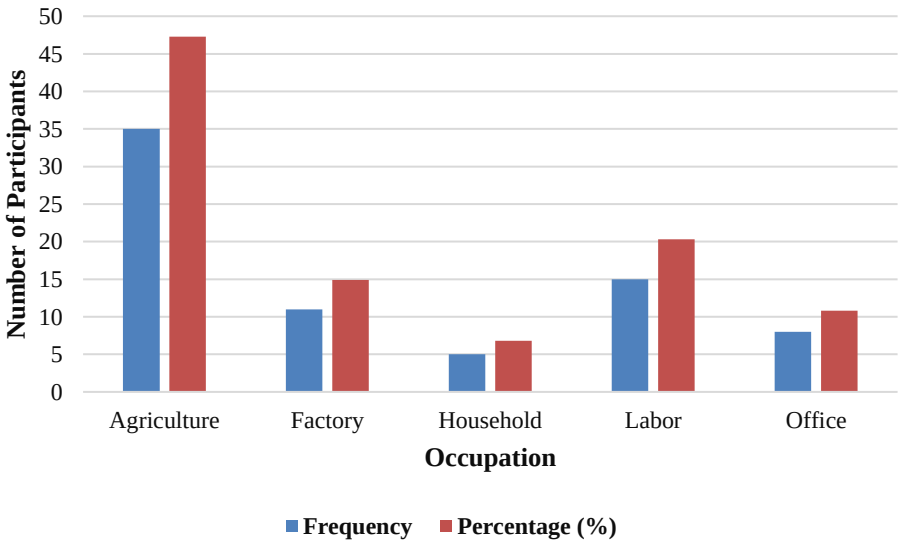

Figure1: Occupation of Study Participants

Figure 1 presents the occupational background of the study participants. The majority (47.3%) were engaged in agriculture, followed by laborers (20.3%), factory workers (14.9%), office employees (10.8%), and household workers (6.8%). The predominance of physically demanding jobs among participants may have implications for cervical spine degeneration and recovery following ACDF. Understanding occupational influences on CSM progression and postoperative outcomes is essential for tailoring rehabilitation strategies and improving surgical success rates.

Table 3 presents the BMI classification of participants, with an equal distribution of non-obese (50.0%) and obese (50.0%) individuals. The objective comparison of postoperative recovery outcomes between the two groups was made possible by this balanced categorization, which aids in determining whether BMI had a substantial impact on neurological improvement after ACDF.

Table2: Distribution of participants according to pre-operative ROM

Pre-operative ROM	**Frequency**	**Percentage (%)**
Unstable	11	**14.86**
Stable	**63**	**85.14**
Total	**74**	**100**

Table 3: BMI Classification of Participants

BMI Classification	**Frequency**	**Percentage (%)**
Non-obese	37	50.0
Obese	37	50.0

Preoperative Assessments

Table 4 illustrates the distribution of cervical lordosis loss among obese and non-obese patients undergoing Anterior Cervical Decompression and Fusion (ACDF). Loss of cervical lordosis was significantly higher in the obese group (67.6%) compared to the non-obese group (40.5%), suggesting a possible association between higher BMI and spinal alignment abnormalities. Conversely, 59.5% of non-obese patients maintained normal cervical lordosis, compared to only 32.4% in the obese group. These findings highlight the need to further explore BMI's role in cervical spine biomechanics and its impact on surgical outcomes.

Table 4: Loss of Cervical Lordosis in Study Groups

Cervical Lordosis Loss	**Obese (n=37)**	**Non-Obese (n=37)**
Present	67.6%	40.5%
Absent	32.4%	59.5%

Table 5 presents the preoperative MRI findings of study participants. The majority (86.5%) exhibited no spinal cord changes, while 13.5% had MRI evidence of cord compression. According to these results, the majority of patients who had symptomatic myelopathy but no discernible radiological signs of spinal cord compression had ACDF. The presence of cord changes in a subset of patients highlights the importance of clinical correlation with imaging findings in diagnosing CSM and guiding surgical decision-making for improved neurological recovery.

Table 5: Preoperative MRI Findings

MRI Findings	**Frequency**	**Percentage (%)**
No Cord Changes	64	86.5
Cord Changes Present	10	13.5

Postoperative Recovery Trends

m-JOA scores were performed at different time points after the postoperative neurological recovery. ACDF surgery was effective as the m-JOA score improved progressively from the preoperative stage to 6 months postoperatively.

Table 6: Distribution of participants according to some Post-operative characteristics. (n=74)

Variables	Descriptive Statistics			
	Mean	**SD**	**Median**	**Range**
Post-operative mJOA Score recovery rate	10.81	13.41	5.00	66.70
Post-operative mJOA score 3 months	12.9459	1.5693	13.00	6.00
Post-operative mJOA Score Recovery Rate1	16.4932	14.5985	16.70	66.70
Post-Operative mJOA Score 6 Months	13.3243	1.5180	13.00	7.00
Post-Operative mJOA Score Recovery Rate2	22.6662	16.1685	20.00	66.70

Postoperative neurological recovery of patients undergoing ACDF for CSM using the m-JOA score are presented in Table 6. Mean postoperative m-JOA scores were 12.95 (3 months) and 13.32 (6 months), and scores improved over time. From initial recovery of 10.81% to 22.67% at 6 months, recovery rates increased, which suggests improvement in time. The high SD and range imply that patient outcome is variable and is influenced by BMI and cervical lordosis. Most patients made steady neurological recovery, but there are individual variations that point out the importance of follow-up studies for longer periods to estimate recovery trends and optimal postoperative care.

Table 7: Distribution of Study subjects as per a few characteristics and pre-op-ROM

Variable	**Pre-operative ROM**		**T statistic**	**p-value**
	Instable(n_1=11)	Stable(n_2=63)		
	mean±SD			
Age	55.44±12.09	48.97±14.29	1.2925	0.2004
Duration of symptoms (months)	10.78±15.17	12.32±10.27	0.3948	0.6942
BMI	30.81±4.70	26.49±5.83	2.1220	0.0374
PRE-operative cervical lordosis	18.56±6.39	17.38±5.52	0.5860	0.5598
Pre-operative m-JOA score	12.33±1.50	11.92±1.59	0.7333	0.4658
Post-operative MJOA score 6 weeks	12.78±1.64	12.59±1.58	0.3363	0.7376
Post-operative MJOA score recovery rate	8.06±14.02	11.28±13.51	0.6664	0.5073
Post-operative MJOA score 3 months	13.11±1.62	12.92±1.60	0.3338	0.7395
Post-operative MJOA score recovery rate1	13.52±17.53	17.18±14.32	0.6964	0.4885
Post-operative MJOA score 6 months	13.56±1.74	13.30±1.52	0.4607	0.6464
Post-operative MJOA score recovery rate2	21.77±20.99	23.25±15.54	0.2559	0.7988

Preoperative range of motion (ROM) stability is compared in unstable (n=11) and stable (n=63) patients undergoing ACDF for CSM in Table 7. Other variables did not show any significant differences, but BMI was significantly higher in the unstable group (p=0.0374). Both m-JOA scores improved over time, both preoperatively and postoperatively, but there was no big difference in recovery rates between the two groups. Postoperative m-JOA scores at 6 weeks, 3 months, and 6 months were slightly higher in the unstable group, but p values were always greater than 0.05 and, therefore, not statistically significant. This implies that neurological recovery following ACDF surgery is not dependent on ROM stability.

Statistical Findings

A correlation analysis was made between BMI, cervical lordosis, and m-JOA score improvement after ACDF surgery. Overall, analysis did not show any relationship between BMI and neurological recovery (p=0.793), and therefore BMI itself was not a strong predictor of post-surgical outcomes.However, a moderately good correlation (r=0.502, p=0.000) between cervical lordosis and preoperative neurological function suggested that this lordosis was involved in baseline neurological condition. Yet preoperative degrees of cervical lordosis had no significant impact on postoperative m-JOA improvement (p = 0.824), suggesting that preoperative alignment of the cervical spine had little effect on the postoperative outcomes, as shown in Table 8.

Table 8: Correlation of BMI and Cervical Lordosis with m-JOA Score Improvement

Variable	Pearson Correlation Coefficient	p-value
BMI vs. m-JOA Improvement	0.031	0.793
Cervical Lordosis vs. Preoperative m-JOA	0.502	0.000
Cervical Lordosis vs. Postoperative m-JOA	0.142	0.824

Postoperative recovery outcomes are compared between obese and non-obese patients following ACDF surgery in Table 9. The mean postoperative m-JOA score was slightly lower in the obese group (12.59± 1.58) than in the non-obese group (12.92± 1.60). In the same way, the mean recovery rate was lower in obese patients (21.77%) than in non-obese patients (23.25%), but p-values (0.507 and 0.488) did not indicate a statistically significant difference. This implies that obesity does not play a major role in neurological recovery after ACDF.

Table 9: Comparison of Recovery Outcomes Between Obese and Non-Obese Patients

Group	Mean Postoperative m-JOA	Mean Recovery Rate (%)	p-value
Obese	12.59 ± 1.58	21.77 ± 20.99	0.507
Non-Obese	12.92 ± 1.60	23.25 ± 15.54	0.488

Discussion

This study aimed to determine the influence of Body Mass Index (BMI) and Cervical Lordosis on the neurological recovery of patients undergoing ACDF for CSM. This study attempted to determine whether BMI, cervical alignment, and post-surgical recovery trends have a significant influence on neurological outcomes after ACDF by assessing the relationship between these factors.

The findings of the study showed no significant correlation between BMI and neurological recovery (p=0.793), and therefore, BMI alone is not a strong predictor of post-surgical outcomes. Cervical lordosis did, however, show a moderate positive correlation to preoperative neurological function (r=0.502, p=0.000), suggesting that the presence of cervical lordosis played a role in the presence of neurological status before surgery. However, cervical lordosis did not have a significant effect on postoperative recovery (p=0.824), and therefore, surgical outcomes may be more dependent on the surgical intervention itself rather than preoperative spinal curvature. Patients with higher BMIs did not differ statistically significantly (p>0.05) from those with lower BMIs in terms of recovery rates or m-JOA score settlement. This is consistent with previous literature that obesity may be associated with intraoperative challenges and postoperative complications without negatively affecting neurological recovery after decompression.

There have been debates about the relationship between BMI and cervical alignment and spinal surgery outcomes. There are, however, some studies showing that higher BMI is associated with an increase in surgical complexity, prolonged recovery time, and an increased rate of complications, including wound infections, delayed fusion, and an increase in perioperative morbidity [18, 19]. Nevertheless, other studies comparable to this study have not found a direct link between BMI and neurological recovery after ACDF [20].

As far as cervical lordosis, the majority of prior research has reported a correlation between preoperative spinal alignment and long-term functional outcome, with some studies supporting the intervention of corrective measures aimed at optimizing postoperative recovery [21]. Zhang et al.. (2017) showed postoperative residual nervous deficit with severe preoperative cervical kyphosis [22]. Nevertheless, the present study does not support the above notion, as no significant effect of cervical lordosis on postoperative recovery was found (p=0.824). Consistent with Al-Adli et al. (2024), reported similar findings, namely that cervical curvature does not strongly dictate postoperative improvement in ACDF patients but may impact preoperative neurological function [23]. Evaluation and treatment of patients having ACDF for CSM are among the clinical implications of the study's findings. BMI shouldn't be the main factor in surgical decision-making because this study shows that it has no discernible impact on neurological recovery. Preoperative spinal curvature correction is not essential in ACDF procedures, as cervical lordosis does not strongly predict postoperative outcomes, and similarly, while preoperative neurological function is influenced by cervical lordosis, it does not strongly predict postoperative outcomes. This suggests more patient-oriented interventions utilizing an indication based on functional impairment and symptomatology rather than BMI or cervical alignment alone. In terms of patient

counseling, those with higher BMI or altered cervical alignment can be reassured that these factors are not major barriers to successful recovery after ACDF. Specifically, it is important to respond to questions about surgical eligibility, postoperative expectations, and planning for rehabilitation. In addition, results demonstrate that, unlike prior studies that compare outcomes between low and high BMI patients, the focus should be placed on individualized postoperative care, whereby patients receive targeted rehabilitation programs to maximize functional outcomes regardless of cervical curvature or BMI.

However, the study has several limitations to be acknowledged. The duration of neurological recovery during the six-month follow-up period that is used to examine the relationship between functional improvement and changes in BMI or cervical lordosis may lead to their inability to assess a delayed effect of BMI or cervical lordosis on functional improvement. Longer follow-up durations (1 to 3 years and even more) could serve for a better study of the long-term outcomes. Second, the findings may be limited in generalization to the overall population since this is a single-center study and also due to differences in surgical techniques, patient demographics, and rehabilitation protocols. The external validity of the results could be improved by multi-center trials with different patient populations. m-JOA scores for neurological assessment were primarily used, while they are validated, but not functional and quality of life outcomes. Future research should include patient-reported outcome measure (PROM) and gait analysis as well as biomechanical assessment to further understand post-surgical recovery.

Future research should address long-term follow-up studies to determine if BMI and cervical lordosis are progressive in neurological improvement beyond six months. This will also clarify if certain delayed structural or metabolic effects influence recovery trajectories. In addition, this study's lower external validity and generalizability will be improved with larger, multi-center trials conducted in multiple hospitals and with a broader patient population. Future studies should evaluate how cervical curvature affects postoperative cervical biomechanics since biomechanical modeling and patient-reported functional outcomes are not part of present studies beyond traditional clinical assessments. In addition, the effect of comorbidity, including hypertension and diabetes, is also to be further explored in modulating recovery outcomes.

Conclusion

The objective of this research was to ascertain how Cervical Lordosis and BMI affected neurological recovery after ACDF for Cervical Spondylotic Myelopathy (CSM). The first was that there was no significant correlation between BMI and surgical neurological improvement, and BMI did not predict postoperative neurological improvement. Cervical lordosis was moderately correlated with preoperative neurological function but did not affect the postoperative recovery of the m-JOA score. These results indicate that the effect of ACDF surgery is not affected by variation in BMI category or cervical alignment. These findings from a clinical perspective are useful for surgical decision-making and patient counseling. The study supports that patients with higher BMI or altered cervical alignment should not be discouraged from having an ACDF as these factors do not significantly hinder neurological recovery. Finally, cervical lordosis affects baseline (but not postoperative) function in an additive fashion, such that correction of cervical alignment may not be needed in all cases. However, although many of the strengths are recorded, the study was limited by the short follow-up duration (six months), single-center design, and relatively small sample size (74). Multicenter trials with longer follow-up periods are necessary to further validate the findings because these factors may limit the results. Research on the long-term effect of BMI and cervical lordosis on ACDF outcomes should include functional assessments, patient-reported outcomes, and biomechanical modeling. Further understanding of the factors that contribute to the best possible neurological recovery following ACDF surgery can be obtained through investigation of the impact of comorbidities and rehabilitation strategies.

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