The Effect of Lumbar Decompression on Functional Transitions in Patients with Lumbar Spinal Stenosis: Clinical and Biomechanical Evidence

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INTRODUCTION: The prevalence of degenerative lumbar stenosis is estimated to range from 11-39% in adults, with 62% of these patients reporting neurogenic claudication. Lumbar Stenosis with Neurogenic Claudication (LSNC) is defined as generalized weakness in the lower extremities exacerbated by walking and relieved with sitting that may be accompanied by cramping, pain, or paresthesias with progression of stenosis. The Sit to Stand (StS) has high verisimilitude to everyday movements as it replicates the functional transitions required to perform Activities of Daily Living (ADLs). This task is an objective measure of functional impairment, which has been found to correlate with visual analog pain scores in patients with back and leg pain in prospective studies. However, the range of motion and joint angles in LSNC patients have not been firmly established. This study has two aims: (1) to identify and quantify disability and impaired movement patterns in patients with LSNC before surgery and compare them to healthy age-matched controls, and (2) to investigate the effect of lumbar decompression on these patterns in patients 3 months postoperatively.

METHODS: This study was a retrospective, single-center, concurrent cohort study comprised of patients from five contributing spine surgeons. Institutional review board (IRB) approval was obtained for this study. For Aim 1, thirty-seven patients diagnosed with LSNC and fourteen age-matched controls were included in this study. Controls had no spine-related symptoms or diagnosis. Subjects are included if their age is between 45 and 68. LSNC patients were tested one week before surgical intervention, and controls were tested on a date convenient for the subject. For Aim 2, thirty-six LSNC patients completed testing both one week before surgery and 3 months after surgery. Before each visit, the patients completed the Oswestry Disability Index (ODI), Patient-Reported Outcomes Measurement Information System (PROMIS), and Tampa Scale of Kinesiophobia (TSK) questionnaires. All participants were fitted with a full-body external reflective marker set for three-dimensional (3D) analysis (VICON Nexus 2.16) at a sampling rate of 100 Hz. Each subject performed three StS trials with the instructions to place their hands on their laps when they sit down and not to use their arms to push off from the legs to assist the transition. All raw data were exported and processed using a custom laboratory algorithm using MATLAB. The data were analyzed using a linear mixed-effects model in R (R 2025.5.1.513).

RESULTS: The NSLC cohort required a mean of 1.4 seconds preoperatively and 1.6 seconds postoperatively to complete the sit-to-stand task, compared with 0.9 seconds in the control group. Compared to control, the NSLC group prior to surgery exhibited a lesser range of motion with hip flexion (Left: 55.9° vs 66.7°, P=0.0046; Right: 54.3° vs 66.1°, P=0.0022), and greater range of motion with hip adduction(Left: 10.2° vs 6.7°, P=0.0200; Right: 10.5° vs 8.4°, P=0.1695) and rotation (Left: 25.2° vs 16.3°, P=0.0092; Right: 26.2° vs 16.4°, P=0.0355). The joint angles at the transition from sitting to standing, which is defined as the maximum trunk forward lean, were analyzed. The NSLC group exhibited lesser hip (Left: 74.1° vs 84.4°, P=0.0924; Right: 72.6° vs 84.4°, P=0.0346) and knee flexion (Left: 69.7° vs 81.1°, P=0.0176; Right: 69.2° vs 82.8°, P=0.0100). At 3 months post-surgery, the NSLC patients show a lesser range of motion of hip adduction (Left: 8.3° vs 9.4°, P=0.0065; Right: 9.7° vs 10.3°, P=0.1465) and rotation (Left: 22.1° vs 24.5°, P=0.0271; Right: 23.7° vs 29.2°, P=0.0027) compared with preoperative values. At max trunk forward lean, patients show more knee flexion postoperatively (Left: 71.7° vs 66.4°, P=0.0016; Right: 72.6° vs 69.0°, P=0.1197), and less thorax anterior tilt (20.9° vs 27.4°, P<0.001). At three months after surgery, patients had lower disability level (Average ODI: 23.0 vs 41.3), reduced fear of movement (Average TSK: 35.6 vs 43.5), improved physical function (Average PROMIS physical function: 41.8 vs 34.8), reduced pain interference (Average PROMIS pain: 55.1 vs 65.3), and better mood (Average PROMIS mood: 35.6 vs 48.1).

DISCUSSION: Patients with LSNC required significantly longer times to complete the sit-to-stand task, reflecting impaired efficiency and functional capacity. Range-of-motion analyses revealed bilateral reductions in hip flexion, suggesting difficulty in generating forward trunk momentum, likely secondary to weakness, stiffness, and pain-avoidance strategies. At maximum trunk lean, LSNC patients demonstrated reduced hip and knee flexion, indicative of a stiffer movement strategy that may minimize lumbar loading but constrains center-of-mass displacement, thereby prolonging task completion. This compensatory rigidity, while protective, may increase stress on adjacent joints. Lumbar decompression resulted in measurable improvements in sit-to-stand mechanics. At three months postoperatively, patients demonstrated increased knee flexion and reduced thoracic tilt at maximum forward lean, reflecting a shift from trunk-dominant to lower extremity–driven momentum generation. These adaptations indicate reduced reliance on compensatory trunk flexion, improved biomechanical efficiency, and decreased spinal loading during functional transitions. Postoperative reductions in hip adduction and rotation further suggested enhanced stability. Collectively, these findings support the role of decompression in restoring safer and more balanced movement strategies in LSNC patients.

SIGNIFICANCE/CLINICAL RELEVANCE: This study underscores the value of advanced motion capture technology in delineating compensatory movement strategies during functional transitions in patients with LSNC. Importantly, findings demonstrate that lumbar decompression surgery is associated with measurable improvements in transition mechanics, reducing compensatory trunk reliance and promoting more efficient, stable, and biomechanically favorable movement patterns. These adaptations suggest that surgical intervention not only alleviates disability but also facilitates restoration of safer functional mobility.

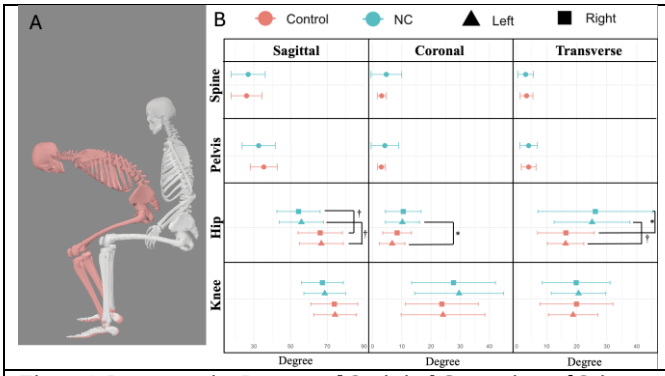

Figure 1. Representative Images and Statistical Comparison of Spine and Lower Extremity Kinematics Range of Motion during Sit-to-Stand Task. *(A) Skeleton showing the sitting in white and peak trunk flexion in red. (B) A comparison of spine, pelvis, hip, and knee range of motion on sagittal, coronal, and transverse planes during the transition from sitting to standing. p < 0.05 (*), and p < 0.01 (†).*

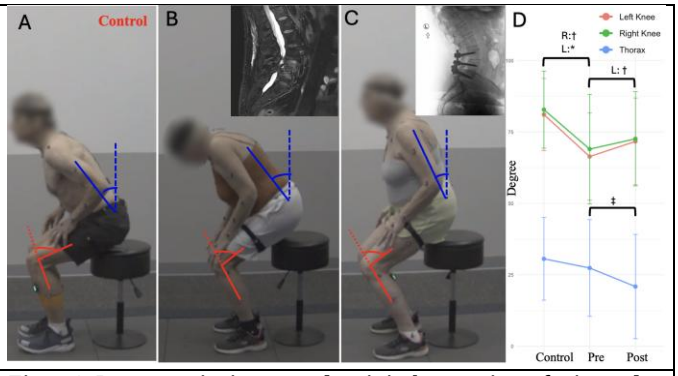

Figure 2. Representative images and statistical comparison of spine and knee kinematics at the transition phase of the Sit-to-Stand task. *Representative image of (A) a healthy control subject, (B) an NSLC patient pre-surgery, (C) an NSLC patient 3 months post-surgery. (D) A thorax and knee flexion angles comparison during the transition from sitting to standing. p < 0.05 (*), p < 0.01 (†), and p < 0.001 (‡).*