Biomechanical Evaluation of a Synthetic L3-S1 Spine Model

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Introduction: An anatomically and mechanically correct model of the human lumbar spine is necessary for research and development of new implants and surgical procedures indicated for low back problems. Human cadavers currently represent the gold standard, but they have large inter-specimen variances, alter in mechanical properties over time, and can be difficult to obtain. Pacific Research Laboratories (Vashon, WA) has developed the Sawbones spine model (SBSM) to overcome these limitations.

Purpose: The purpose of this study was to compare the mechanical properties of SBSM to human cadaveric lumbar spines.

Methods: We obtained an L3-S1 SBSM and 39 comparable fresh frozen human cadaver spines, with a mean age of 52 years (range, 34-63 years). Each L3-S1 spine was mounted and loaded in flexion and extension with the movements of each vertebral body tracked in 6 degrees of freedom. A 200 N follower load and a 200 N gravity load was applied throughout the flexion-extension loading to a peak of ±5.0 Nm at 0.25 Hz. Readings were recorded for the movements and the loads and displacements of the MTS. This procedure was continued for axial torsion to ± 5 Nm at 0.25 Hz.

The SELSPOT 3D Motion Measurement System was used to track the motion segment unit movement throughout testing. A triad consisting of three LEDs was fixed to the sacrum and each vertebral body, and the SELSPOT system measured their three-dimensional coordinates. The first sacral vertebra was potted into a base which remained stationary relative to the testing apparatus. From the relative change in position of each of the three LED markers at each level, the three-dimensional motion of the vertebra was calculated.

The overall stiffness of each L3-S1 spine was calculated from load-displacement curves for each construct for flexion-extension and axial rotation. The range of motion of the spinal segments was calculated from the kinematic motion data acquired via attached LED sensors to the anterior of the vertebral bodies.

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Results: The structural stiffness for the L3-S1 SBSM was recorded as 2.70 N/mm in flexion and 1.97 N/mm in extension, and 2.54 Nm/° in torque. Average stiffness for 39 cadaver spines was 5.11 ± 3.96 N/mm in flexion (range 0.55 – 16.56), and 6.99 ± 4.02 N/mm in extension (range 0.05 – 19.57), and 1.94 ± 0.79 Nm/° in torque (range 0.46 – 3.67). The sagittal motion of the motion segment units in the SBSM was recorded as 12.13° at L3-4, 6.19° at L4-5, and 6.08° at L5-S1. The motion for torque axial rotation was measured as 2.27° at L3-4, 0.64° at L4-5, and 0.60° at L5-S1. The average sagittal motion for 15 cadaver spines was 5.04 ± 3.18° at L3-L4, 8.71 ± 3.27° at L4-L5, and 7.11 ± 4.02° at L5-S1. The average motion for torque axial rotation of 27 cadaver spines was 1.22 ± 1.33° at L3-4, 0.92 ± 0.75° at L4-5, and 0.82 ± 0.65° at L5-S1.

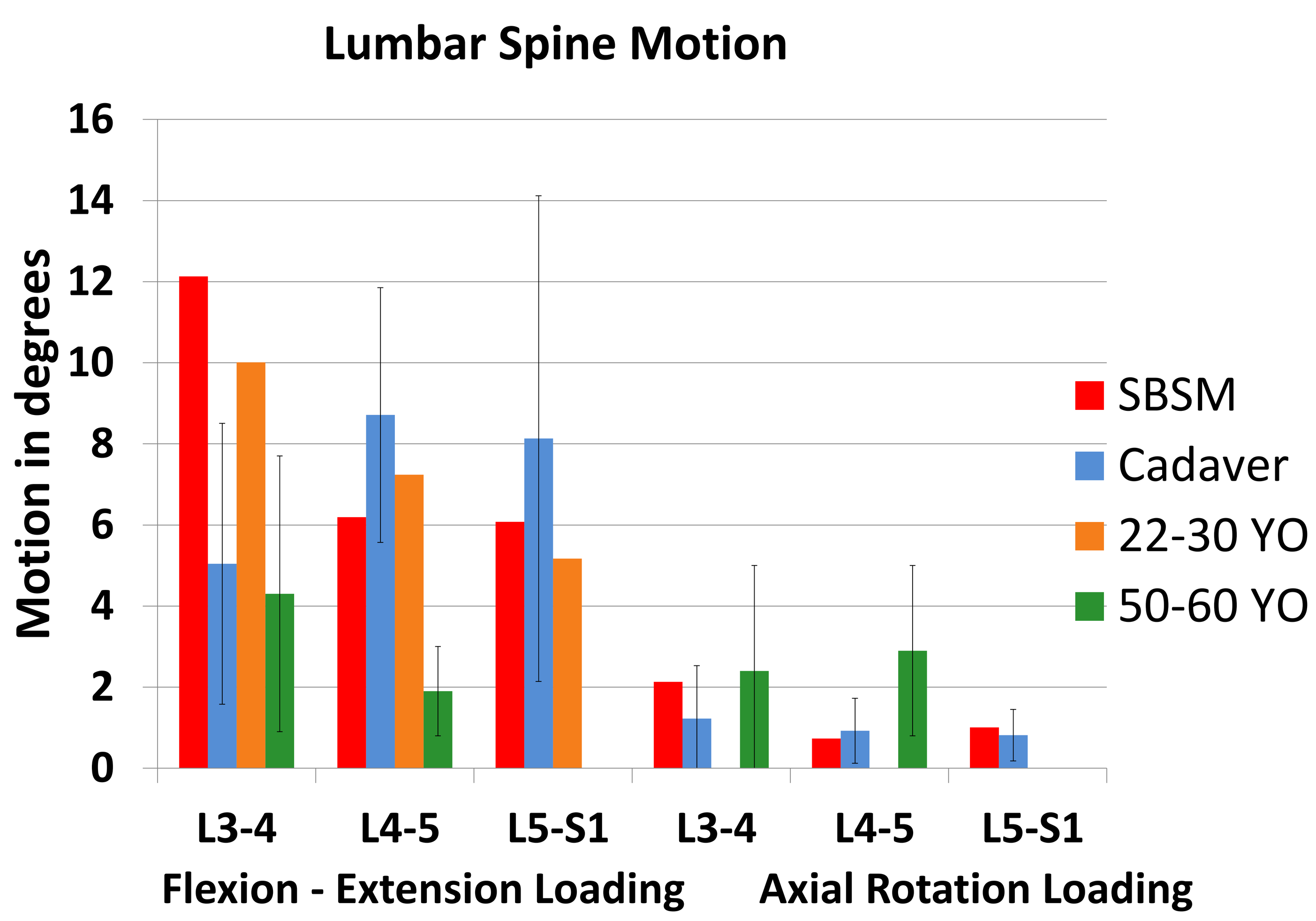

Figure 1 – Measures for the SBSM are compared to cadavers (shown with standard deviation brackets) and to the motion measured in young, normal individuals, 22-30 years old.[1] The measures in older healthy subjects is shown with standard deviation brackets.[2] Note the wide variability of the studies.

ACKNOWLEDGEMENTS: This project was supported by the Max Biedermann Institute for Biomechanics Research, Mount Sinai Medical Center, Miami Beach, FL

Discussion: The SBSM showed much greater motion in flexion-extension at L3-4 compared to the cadaver spines, but the cadaver spines showed great variability and at L4-5 and L5-S1, the range of motion for the SBSM remained within one standard deviation of the average cadaveric data. For axial rotation, the SBSM was within one standard deviation of the average cadaver rotation for all levels tested.

The SBSM motion we measured at each level was better matched to that of young healthy individuals as reported in the literature[1] than to our cadavers ranging from 34 to 63 years old. On the other hand, older healthy individuals showed significantly decreased motion in flexion and extension at each level, with even more limitations than our measures in cadaver spines averaging 52 years old.[2] Despite our goal of achieving "physiologic" load levels (± 5 Nm), this may have been too far beyond the neutral zone to allow comparisons with those studies in live subjects. These comparisons are shown in Figure 1. Although the motion in both the cadaveric and live subjects from older adults was attenuated, none of these individuals had enough degeneration to be considered surgical candidates. Further studies may be warranted to determine appropriate models for spines that are requiring surgery.

Significance:
A lumbar spine model that is anatomically equivalent and mechanically similar to the human spine can be used in the development of new implants and surgical procedures indicated for low back pain.

References: 1) Wong, KWN, et al, Spine, 31-4:414-9, 2006; 2) Li, G, et al, Eur Spine J, 18:1013-21, 2009; 3) White, A, Panjabi, M, Lippincott, 1990

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