Lumbar Spine has Higher Three-dimensional Curvature and Intervertebral Disc Deformation in the Standing Position Relative to the Supine Position

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INTRODUCTION: The lumbar spine is the most heavily loaded part of the whole spine. Consequently, lower back pain (LBP) is a common clinical condition with a lifelong prevalence rate reaching 80%. Prolonged standing exacerbates pain in individuals with LBP. Understanding the biomechanical differences between the standing and supine positions will contribute to the understanding of the pathophysiology of lumbar disease, also aid in the prevention, clinical assessment and treatment of lumbar spine conditions. Therefore, this study aimed to investigate the physiological geometric changes of the lumbar spine from supine to standing positions, as well as the differences in three-dimensional (3D) lumbar alignment between these two postures.

METHODS: The Ethical Committee at our institution approved the study (Protocol Number: 2021-011-SK). Twenty-five subjects without lumbar spine disorders (9 males, 16 females, mean age: 24.8±3.49 years, mean BMI: 21.20±2.05 kg/m^2) were included in this study. All participants underwent lumbar spine computed tomography scans in the supine position and dual-plane digital radiography (TAOiMAGE, Shanghai, China) in standing position to obtain the 3D structures of the lumbar spine in both positions. The vertebral endplates were represented as triangular meshes. The singular value decomposition method was used to calculate the normal vectors of each endplate. This allowed for the calculation of 3D parameters such as lumbar lordosis angle, intervertebral disc angle, sacral scope angle, and intervertebral disc height. The intervertebral disc deformation was quantified by calculating the coordinates difference of the upper endplate vertices in the local coordinate system of the lower endplate between the two positions and normalized by the intervertebral disc thickness. A two-sample t-test was used to determine if there were significant differences in the parameters between the two positions, with the significance level set at $p<0.05$.

RESULTS SECTION: The lumbar lordosis angle in the standing position was significantly greater than in the supine position (38.45±10.67 vs. 27.56±10.81, p=0.0007), while the sacral scope angle showed no significant difference (36.95±5.29 vs. 36.45±5.88, p=0.7560). Except for the L4/5 intervertebral disc, all other discs exhibited statistically significant differences in their intervertebral disc angles. In the standing position, the height of the L5/S1 intervertebral disc was significantly smaller than in the supine position (5.59±1.81 vs. 6.97±1.21, p=0.0028). Compared to the supine position, the anterior part of the intervertebral discs (L1/2, L2/3, L3/4) in the standing position experienced stretching deformation, while the posterior part underwent compression deformation, resulting in an overall posterior shear force direction. The L4/5 intervertebral disc did not show significant compression or shear deformation. The L5/S1 intervertebral disc experienced approximately 30% compression deformation relative to its disc thickness with an overall anterior shear force direction.

DISCUSSION: The statistical differences in the 3D lumbar spine parameters between the two positions indicated that the supine imaging techniques cannot accurately assess the alignment of the lumbar spine during weight-bearing standing positions. Compared to other lumbar intervertebral discs, the L5/S1 disc underwent significant compression deformation in the standing position, suggesting that it was at a higher risk of degeneration and injury. The intervertebral discs at L1/2, L2/3, and L3/4 experienced posterior deformation in the standing position, which may lead to posterior disc protrusion of these segments with prolonged standing. The L4/5 intervertebral disc did not show significant strain between the standing and supine positions, and the reasons for potential disc injury in this segment require further investigation.

SIGNIFICANCE/CLINICAL RELEVANCE: Individuals with L5/S1 disc protrusion should avoid prolonged standing. The population who need to stand for extended periods should regularly perform lower back stretching exercises to ensure the balance of forces on the lumbar intervertebral discs.

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IMAGES AND TABLES:
Table 1. Differences in 3D Lumbar Spine Parameters between Standing and Supine Positions (* indicates significant differences)

parameters	Standing	Supine	*P*-value
Lordosis(°)	38.45±10.67	27.56±10.81	0.0007*
sacral scope(°)	36.95±5.29	36.45±5.88	0.7560
L1/2 angle(°)	6.73±2.41	3.73±1.7	0.0000*
L2/3 angle (°)	8.55±3.08	4.61±2.4	0.0000*
L3/4 angle (°)	10.8±2.72	7.38±2.52	0.0000*
L4/5 angle (°)	12.89±3.81	11.68±2.69	0.2006
L5/S1 angle (°)	10.36±4.93	14.31±4.38	0.0043*
L1/2 height(mm)	6.72±1.12	6.29±0.81	0.1320
L2/3 height (mm)	7.63±0.99	7.42±0.75	0.4147
L3/4 height (mm)	8.26±1.05	8.18±0.85	0.7861
L4/5 height (mm)	8.43±1.16	8.5±1.06	0.8167
L5/S1 height (mm)	5.59±1.81	6.97±1.21	0.0028*

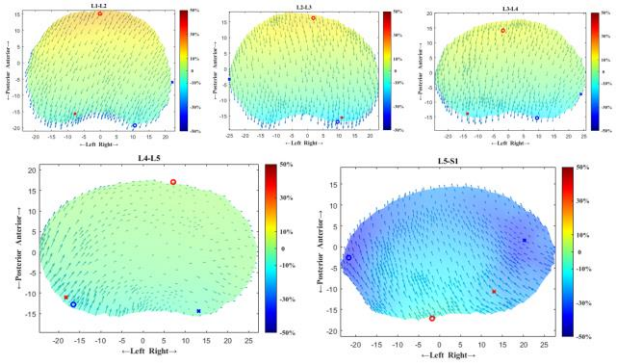

Figure 1. Distribution of Intervertebral Disc Deformation between Standing and Supine Positions. Stretching (in red, 50%) / Compression (in blue, -50%) strain is represented using a gradient color scale. Shear deformation is indicated by the direction and length of the arrows.