Dynamic Motion Characteristics of the Lower Lumbar Spine during Weight-lifting Extension - Implication to Lumbar Pathology and Surgical Treatment

Minfei Wu¹,², Shaobai Wang, PhD¹, Sean J. Driscoll¹, Thomas D. Cha, MD, MBA¹, Kirkham B. Wood, MD¹, Guoan Li, Ph.D³.
¹Massachusetts General Hospital, Boston, MA, USA, ²China-Japan Union Hospital of Jilin University, Changchun, China, ³Massachusetts General Hospital and Harvard Medical School, Boston, MA, USA.

Disclosures:

Introduction: Lumbar degenerative disc diseases are often found in the lower lumbar levels of L4-5 and L5-S1. Altered vertebral motion has been widely assumed as a biomechanical factor causing spinal pathology. However, the in-vivo dynamic motion characteristics of the L4-5 and L5-S1 motion segments are still not clearly described in literature. The data may have important implementation to understand spinal kinematics and to specify the vertebral motion features related to various disc diseases. The objective of the study is to investigate the in-vivo segmental motion patterns of the human lumbar spine during weight-lifting from a flexion position to full extension position and compare the lower levels with the upper levels using a 3D fluoroscopic imaging technique.

Methods: Ten asymptomatic subjects (5 males and 5 females, aged 40-60 years old) were recruited. The lumbar segments of L2 to S1 of each subject was MRI scanned to construct 3D models using an established protocol [1]. The lumbar spine was then imaged using a dual fluoroscopic system [2] as the subject performed a weight-lifting activity with each hand holding an 8 pound dumbbell from a flexion position (45°) to a maximal extension position (Figure 1). The fluoroscopes captured the dynamic spinal positions at 30 frames per second with an 8 milli-second pulse. The 3D vertebral models and the fluoroscopic images were used to reproduce the in-vivo vertebral positions along the motion path. The relative translation and rotation of each vertebral segment were analyzed based on vertebral local coordinate system on each segment (Figure 2). ANOVA was used to analyze the kinematics at different vertebral levels and a statistical difference was defined as p<0.05.
Results: The 4 vertebral motion segments, L2-3, L3-4, L4-5 and L5-S1, rotated similarly during the weight lifting motion. The ranges of posterior translation were similar between L2-3 and L3-4. L4-5 had a posterior translation of 2.9±1.5mm, which was significantly higher than that of L5-S1 (p<0.05, Table 1, Figure 3). L2-3 and L3-4 showed similar proximal-distal translations of 1.5±0.4 mm and 1.0±0.4 mm, respectively. L4-5 and L5-S1 had similar compression at the beginning of the lifting activity. However, L4-5 was under compression during the entire weight lifting activity with a proximal-distal translation range of 1.7±0.7 mm. L5-S1 had a proximal-distal translation range of 2.8±0.9 mm, which was larger than the L4-5 (p<0.05).
Discussion: There was no statistical difference in the flexion-extension range of motion among the studied lumbar segments of L2-S1 during the dynamic weight lifting flexion-extension activity. However, we found distinguish motion characteristics of the lower lumber segments of L4-5 and L5-S1, usually larger in translation, than the upper segments. The level dependent differences could be useful to explain higher incidence of degeneration at the lower levels and provide baseline information for motion preservation surgeries.

Significance: The lower lumbar motion segments L4-5 and L5-S1 showed larger translation and compression during the weight-
lifting motion than the upper vertebral motion segments. The data may provide insight into the understanding of lower lumbar disease development and the improvement of motion preservation surgical treatments.

Acknowledgments: This study was supported by the NIH (R21AR057989) and Depuy-Synthes USA research fund.


Segmental 6DOF ROM during the activity. p<0.05: # between levels * all levels

<table>
<thead>
<tr>
<th>.</th>
<th>Translation (mm)</th>
<th>Rotation (deg) .</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A-P</td>
<td>P-D</td>
</tr>
<tr>
<td>L2-3</td>
<td>1.7±1.0</td>
<td>1.5±0.4</td>
</tr>
<tr>
<td>L3-4</td>
<td>2.1±1.0</td>
<td>1.0±0.4</td>
</tr>
<tr>
<td>L4-5</td>
<td>2.9±1.5#</td>
<td>1.7±0.7</td>
</tr>
<tr>
<td>L5-S1</td>
<td>1.4±1.1#</td>
<td>2.8±0.9*</td>
</tr>
</tbody>
</table>

ORS 2014 Annual Meeting
Poster No: 0094