Intervertebral Kinematics Correlate with T2 Relaxation Times in the Lower Human Cervical Spine

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Introduction: Quantitative MRI protocols, such as T2 mapping, have recently been used to evaluate intervertebral disc health. T2 relaxation times have been shown to correlate with disc biochemical composition (water content) and could potentially help detect early stages of disc degeneration [1, 2]. Studies have also found T2 relaxation times to correlate with both Pfirrmann grade and age [3, 4]. While disc quality likely affects spinal segment motion, the relationship between T2 relaxation times and in-vivo intervertebral kinematics during functional activities is unclear. Therefore, the objective of this research was to investigate the correlation between in-vivo T2 relaxation times and six-degree-of-freedom (6DOF) range of motion during dynamic flexion-extension in the C5-C6 and C6-C7 intervertebral levels.

Methods: 7 asymptomatic subjects (3 males, 4 females, average age: 38.4±9.9 years, average BMI 23.7±3.3 kg/m2) were recruited to investigate the correlation between lower cervical spine T2 relaxation times and kinematics. Subjects were imaged using a 3.0 T MR scanner and a sagittal multi-echo spin-echo sequence (TE: 21.8, 32.7, 43.6, 54.5, 65.4, 76.3, 87.2, 98.1, 109.0 ms; TR: 1810 ms; voxel size: 0.9375 x 0.9375 x 4.0000 mm; image size: 256 x 188 pixels). The mid-sagittal image was selected for T2 relaxation time analysis. Intervertebral discs were then divided into five equal area rectangular regions-of-interest (ROIs), centered along the mid-line of the disc (Figure 1). T2 relaxation time values of the center ROI (representing the nucleus pulposus (NP)) were calculated using a mono-exponential fit (OsiriX).

Subjects were also imaged using a 3D dual-fluoroscopic imaging system (DFIS) as they moved dynamically through their full flexion-extension range of motion (Figure). 3D vertebral models of the C5-C7 vertebrae were constructed for all subjects from a proton density weighted MRI sequence. The models and fluoroscopic images were then used to reproduce the vertebral positions along the dynamic motion path of one full flexion-extension cycle. Intervertebral kinematics in 6DOF were calculated from local coordinate systems, established in the center of the vertebral bodies, as the motion of the superior vertebrae relative to its adjacent inferior vertebrae (Figure 2). Dynamic range of motion (DROM) was calculated from the maximum and minimum values of each DOF throughout the cycle.

The T2 relaxation times of the NP for each disc were correlated with DROM in all 6DOF using Pearson Correlation Tests.

Results: Table 1 displays the correlation results for the C5-C6 and C6-C7 discs. In general, an increase in T2 relaxation times of the NP correlated with an increase in coupled rotations (lateral side-bending,
twisting) and translations (medial-lateral) during the flexion-extension activity, particularly at the C6-C7 level. This reveals a relationship between disc health and mobility.

**Discussion:** In-vivo T2 relaxation times of asymptomatic intervertebral cervical discs were correlated with 6DOF DROM during dynamic weight-bearing flexion-extension. The data suggests an increase in T2 relaxation times of the NP correlates with increases in coupled rotations and translations at the C5-C6 and C6-C7 levels during cervical flexion-extension. This is the first study to examine the relationship between in-vivo T2 relaxation times and functional motion. Future work will expand our sample size of asymptomatic subjects and examine this relationship in patients with cervical disc degeneration.

**Significance:** The results of this study reveal a relationship between disc health and 6DOF kinematics. The data suggests an increase in T2 relaxation times is correlated with increased coupled rotations and translations at the C5-C6 and C6-C7 levels during cervical flexion-extension.

![Figure 1](image_url)

**Figure 1:** Intervertebral discs were divided into five equal area rectangular ROIs (1-5), centered along the mid-line of the disc. ROI 1 is most anterior while ROI 5 is most posterior.
Intervertebral kinematics in 6DOF were calculated: flexion-extension rotation (FE), lateral side-bending rotation (SB), axial twisting rotation (Twist), medial-lateral translation (ML), anterior-posterior translation (AP), and superior-inferior translation (SI).

<table>
<thead>
<tr>
<th>T2 Relaxation Time vs. DROM</th>
<th>ML (mm)</th>
<th>AP (mm)</th>
<th>SI (mm)</th>
<th>FE (°)</th>
<th>SB (°)</th>
<th>Twist (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>C5-C6</strong></td>
<td>r-value</td>
<td>0.027</td>
<td>-0.054</td>
<td>-0.051</td>
<td>-0.111</td>
<td>0.431</td>
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<tr>
<td></td>
<td>p-value</td>
<td>0.953</td>
<td>0.908</td>
<td>0.914</td>
<td>0.813</td>
<td>0.334</td>
</tr>
<tr>
<td><strong>C6-C7</strong></td>
<td>r-value</td>
<td>0.888</td>
<td>0.387</td>
<td>0.196</td>
<td>0.177</td>
<td>0.781</td>
</tr>
<tr>
<td></td>
<td>p-value</td>
<td>0.008</td>
<td>0.391</td>
<td>0.674</td>
<td>0.705</td>
<td>0.038</td>
</tr>
</tbody>
</table>

Table 1: T2 relaxation time vs. DROM correlation results for the C5-C6 and C6-C7 levels. r-value indicates Pearson correlation coefficient. Shaded cells indicate statistically significant correlations (p < 0.05).