Thoracolumbar vertebrae position transformation from supine to seated postures

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Introduction

There is significant use for developing subject-specific models, as it has been demonstrated that incorporation of subject specificity can influence vertebral loading predictions. The highest contrast images of vertebrae are obtained from CT scans and most capable machines are restricted to supine postures. However, in crash and aerospace scenarios subjects are seated when experiencing loading; simulations of these events require spine positionings in the seated posture as this can affect injury prediction. The difference in spine curvature between supine and seated postures is most pronounced in the sagittal view of the lumbar region. The objective of this study is to quantify changes in thoracolumbar spine curvature and vertebrae position between supine and seated postures and develop functions for transformation between these postures.

Methodology

Twelve participants (6 male, 6 female) were recruited for a suite of multi-posture scans. Supine magnetic resonance images were obtained capturing the entire thoracic and lumbar spine. A FONAR upright multi-position 0.6T MRI was utilized for seated scans. Upright MRI scans were taken in segments of the upper, middle, and lower torso. AMIRA was used to stitch scans for a single sagittal view of the entire subject spine. For each scan, spinal position was extracted by marking coordinates of the vertebrae centroids. These points were fitted to a cubic spline interpolation to represent spine curvature. To calibrate for differences in scan orientation and position, splines were aligned by minimizing distance between respective vertebrae in the C7-T6 range. A transformation matrix was obtained by taking the difference in position and curvature between seated and supine splines. Radius of curvature was determined by generating approximate arcs for spline segments. All statistical analyses were conducted in SAS with $\alpha=0.05$.

Results and Conclusion

Deviations in the cervical section are influenced by a head support that was present in the seated scans apparatus and not in the supine and are ignored thusly. For each subject, the radius of curvature (RoC) was determined for the lumbar and lower thoracic (T3-T12) region. Paired t-testing revealed a near significant difference in lumbar RoC (seated: 910±768mm, supine: 448±117mm, p=0.0592) and a significant difference in thoracic RoC (seated: 1250±701mm, supine: 817±317mm, p=0.0326). The higher RoC of seated spines suggests straightening of the spine and reduced curvature compared to supine spines. Post-hoc F-testing showed that variance in vertebrae angle is significantly smaller for seated postures than supine for both sexes, corroborating that seated spines are straighter.

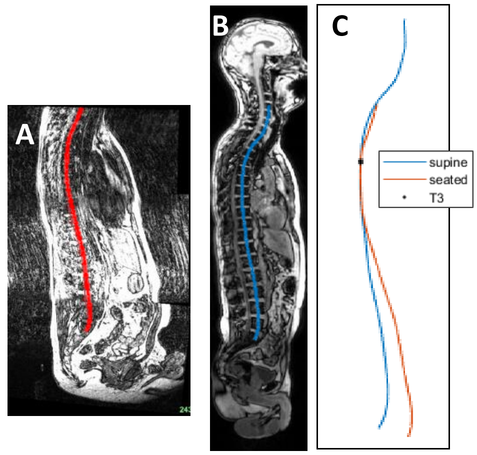

Figure 1. MRI to spline pipeline. Spline fits to seated (A) vs supine (B) scans, (C) Aligned spline data.

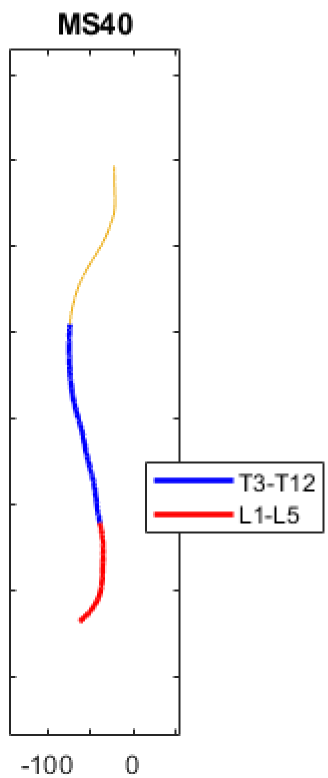

Figure 2. Regions for which radius of curvature was calculated.

Figure 3. Supine-to-seated average transform corridor for 40th percentile male.

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