Lumbar Spine Position in an Automotive Posture Relative to Standing and Seated Flexed Postures

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I. INTRODUCTION

Lumbar disc herniations have been generated in cadaveric component studies with a combination of hyperflexed lumbar spine position and compressive loading [1]. Field data studies demonstrate lumbar spine herniations occur as a result of automotive collisions of various severities and directionality [2], however the amount of lumbar flexion that develops when seated in an automobile remains unknown. X-ray studies have demonstrated that the lumbar spine posture differs between a standing posture and an automotive seated posture but have not quantified the amount of flexion in the lumbar spine relative to a standing or highly flexed posture [3-4]. Additionally, better characterisation of volunteers' initial automotive posture could aid in understanding the loading environment the lumbar spine experiences during a collision. Therefore, the goal of this study was to determine the lumbar spine position of volunteers in a self-selected automotive seated posture, and to quantify that automotive lumbar position relative to a standing and a seated forward-flexed posture.

II. METHODS

A combination of volunteer imaging in an automotive seat and measurements from magnetic resonance images (MRI) was used to determine lumbar spine posture in three different seating positions (volunteer preferred driving posture, standing posture, and forward-flexed posture) of 10 volunteers (5M, 5F; age = 32.2 ± 4.8 years; height 172 ± 11.6 cm; BMI 24.6 ± 3.3). Sagittal angles between each pair of vertebrae were calculated.

Volunteer Measurements and Imaging

Each volunteer was asked to sit in a 2017 Honda Acura TLX driver's seat in their preferred driving posture. In-vehicle measurements were taken and used to replicate this posture while seated in an Upright MRI (Paramed MROpen EVO, ASG Superconductors, Genoa, Italy) in an MR-safe vehicle seat approximating the geometry and stiffness of the TLX seat. For each volunteer, overlapping MRI images were obtained to ensure the entire lumbar spine was imaged in this seated posture. Volunteers were then asked to flex their torsos as far forward as possible (towards their legs) while in the MR-safe seat. A coil was placed on their lower back, and another MRI sequence was obtained. Volunteers were then asked to stand in a relaxed upright posture with their arms resting on a support bar. A coil was placed against the volunteers' lower back while standing and a third MRI sequence was obtained. Volunteer testing methodology was reviewed and approved by the University of British Columbia's Clinical Research Ethics Board. Further detail on volunteers and study methods can be found in Forman *et al*. [5].

Calculation of Sagittal Lumbar Posture

A series of eight points was digitised around the perimeter of the superior and inferior endplates of the T12, L1, L2, L3, L4 and L5 vertebra and the superior articular process of the sacrum. Planes defining these endplates were then fit to each series of points using a least squares method. A centre point for each endplate's coordinate system was identified by finding intersection of the line between the left- and right-most points on the endplates (y-direction, +ve to the right) and the line between the most frontal and dorsal points on the endplates (x-direction, +ve anteriorly). The z-location of the centre point was the location on the plane that was prescribed by the pre-defined centre point x- and y-coordinates. The angle between the x-vectors from centre points of the planes fitted to adjacent superior and inferior endplates in the sagittal plane was calculated for the standing, preferred seated, and forward-flexed postures (-ve angles indicate flexion, +ve angles indicate extension). Within each subject, the intervertebral angles for each spinal level were compared for the three postures (standing, seated, flexed) to determine whether the seated posture generated higher levels of intervertebral flexion than the standing and flexed postures.

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III. INITIAL FINDINGS

The sagittal angles between adjacent vertebrae are reported for all volunteers in the three imaged postures (Fig. 1). When standing, the intervertebral angles in T12-L1 and L1-L2 were relatively neutral (clustered about 0°) compared to the extended angles seen in the lower segments. In the flexed posture, the intervertebral angles in the T12-L1 joint remained similar to the standing angles, whereas the intervertebral angles for L1-L2 through L4-L5 were generally more flexed than the standing angles. The intervertebral angles for L5-S1 in the flexed posture were more varied, with a few subjects exhibiting more extension when flexed than when standing. When seated, the intervertebral angles in the upper three joints were typically between the standing and flexed intervertebral angles. In contrast, the lower three joints were often more flexed when seated than in either the standing or flexed postures. Four of the seven subjects with greater intervertebral flexion at L4-L5 when seated had intervertebral flexion angles that were greater than the other two postures by 5° or more.

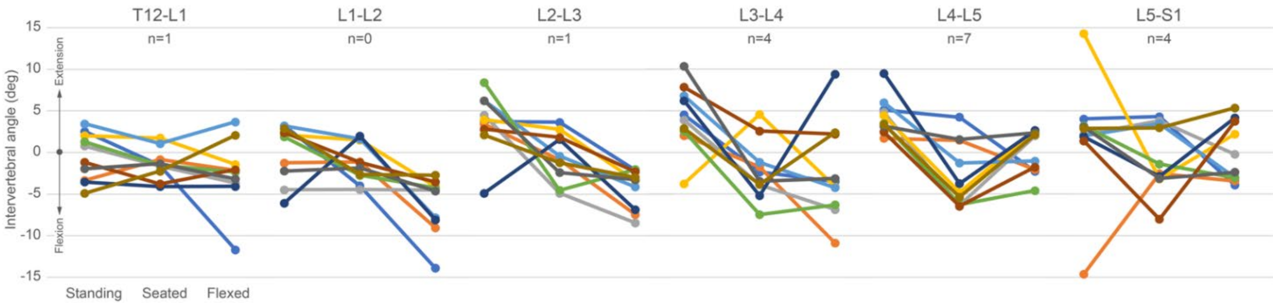

Fig. 1. Intervertebral angles between T12 and S1 for all subjects (shown in a separate colour) for standing (left-most point in each plot), seated (middle point in each plot) and flexed (right-most point in each plot) postures. Extension angles are positive and flexion angles are negative. The number (n) of subjects whose maximum flexion angle while seated exceeded both their standing and flexed postures is shown at the top of each graph.

IV. DISCUSSION

This analysis of the lumbar spine orientations within single individuals across three different postures has shown that the lumbar spine – especially the lower lumbar spine – can be more flexed while seated in a self-selected automotive posture than when either standing or flexing forward while seated. For many volunteers, the automotive seated posture places the lower lumber spine in a more flexed position, which is one of two components needed to generate traumatic lumbar disc herniations in laboratory experiments using cadaveric specimens [1]. Our findings show that this phenomenon occurs most often at the L4-L5 intervertebral joint, which is the most common level for lumbar disc herniations [2]. This phenomenon is also seen at L5-S1, but there is greater variability at this level, possibly due to more observed disc degeneration. The second factor needed for lumbar disc herniations is compression, which prior studies have shown can be generated during a collision (e.g. frontal collisions with lumbar forces measured in a Hybrid-III dummy) [6]. However, further work is needed to assess the magnitude and direction of the dynamic forces generated at each intervertebral level in humans. Our findings are limited by the number of subjects and the possibility that maximum voluntary intervertebral flexion was not achieved by our subjects, particularly in the upper lumbar spine joints. Despite these limitations, our findings highlight the considerable heterogeneity between subjects and even between levels within individual subjects. This heterogeneity suggests that generic models dependent on global metrics (e.g. sex, age) might not be sufficient to predict spinal orientations in different postures; inclusion of local geometric metrics of individuals (e.g. disc height) may be needed to predict lumbar spine orientations in different postures.

V. ACKNOWLEDGEMENTS

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VI. REFERENCES

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