INTRODUCTION

Lower back pain (LBP) is a prevalent musculoskeletal dysfunction and costly societal problem [1]. Research has shown that the incidence of LBP caused by static seated postures can be reduced by promoting dynamic postural changes [2]. These postural changes are facilitated by chairs that support the human body through ranges of seated dynamic movement.

To develop chairs that support dynamic seated movements, a quantitative understanding of the interface between the human and the chair is required. One area of seat interaction is the seatback and of particular interest is the interface at the lumbar region. While several methods exist for quantifying lumbar curvature of a human in static standing postures, few exist for seated postures. Even fewer methods have the capability of capturing dynamic measurements while the subject’s back is obscured by a seatback without requiring modification to the seat. One such method [3] was shown to predict lumbar curvatures from an anterior measure of the relative positions of the ribcage and pelvis for static postures.

The purpose of this research was to utilize the previously reported method to quantify the full range and trajectory of dynamic seated postures. These data can then be used to inform chair design and provide a means to test commercially available chairs that support dynamic postural change.

METHODS

Fifteen subjects (11 female, 4 male, with an average age of 23 (1.6) years) with no reported back pain or spinal injuries volunteered to participate in the research. Each subject was informed of the process and voluntarily provided signed consent.

A three-dimensional motion capture system (Qualisys, Gothenburg, Sweden) was used to quantify two different measures, the relative angular orientation of the subject’s ribcage and pelvis, and the lumbar curvature of the subject. The measure between the ribcage and pelvis was referred to as the openness angle [4] while the lumbar curvature, quantified through a measure of a 3 point arc, was referred to as the lumbar angle (Figure 1).

To measure openness and the lumbar curvature, retro-reflective markers were attached to skin superficial to the sternum, anterior superior iliac spines (ASIS), lateral femoral condyles, seventh cervical vertebra (C7), twelfth thoracic vertebra (T12), and one midway between the posterior superior iliac spines (MidPSIS). Additionally, between T12 and the MidPSIS, markers were placed with a spacing of approximately 1 inch along the spinal column. The most eccentric marker between the T12 and MidPSIS markers was identified as LU.

Subjects were seated on a stool and verbally queued through a continuous motion that started in a self-selected comfortable position. Upon initiation of
the test, subjects were asked to move to their maximum lordotic posture, then to their maximum kyphotic posture, and back to their original position in one continuous motion. Data were collected at 30 Hz for a total of 20 seconds.

For each subject, a time trace of the openness angles and lumbar angles were plotted with the openness angle as the independent variable and the lumbar angle as the dependent variable, Figure 2. A linear regression analysis was then performed on each subject’s data.

The maximum and minimum values of openness angle and lumbar angle for each subject were also taken for comparison to previously collected static data.

RESULTS AND DISCUSSION

For the fifteen subjects the average $r^2$ value was 0.841. Figure 2 shows the same positive trend as the static data reported previously [3], i.e. a larger openness angle corresponds to a larger lumbar angle.

![Figure 2. Sample plot of the dynamic motion occurring during seated postural change. The solid line represents a linear regression analysis of Openness vs. Lumbar Angle for a single subject.](image)

However, it should be noted that while the data suggest the relationship between the two measures is linear, there were exceptions. Some subjects displayed a “loop” as seen in Figure 3. This suggests that while a linear relationship can generally fit the dynamic motion, in a practical sense, more elaborate models are necessary, and may need to occur on a subject by subject basis.

In addition, the ranges of motion for the dynamic tests were compared to the maximum kyphotic and lordotic data collected from static positions. Data in Table 1 show that in both the previous static and current dynamic cases, the openness and lumbar angles cover similar respective ranges. This shows that the dynamic data are consistent with previous findings while providing more information about the path of motion between maximum kyphotic and lordotic positions.

![Figure 3. Sample Regression Analysis of Openness vs. Lumbar Angle for a single subject showing a “loop”.](image)

<table>
<thead>
<tr>
<th></th>
<th>Openness Angle (deg)</th>
<th>Lumbar Angle (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max</td>
<td>Min</td>
</tr>
<tr>
<td>Static Avg</td>
<td>113.8</td>
<td>60.8</td>
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<tr>
<td>SD</td>
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<td>15.4</td>
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<tr>
<td>Dynamic Avg</td>
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<tr>
<td>SD</td>
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<td>11.0</td>
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</tbody>
</table>

CONCLUSIONS

Results demonstrated that the lumbar angle as defined can measure and quantify a lumbar curvature through a dynamic range of motion. Additionally, the relationship between the openness angles and lumbar curvatures across a dynamic range of motion for a given subject can be approximated by a linear approximation. This work allows further characterization of the body seat interface for informing the design of seats.

REFERENCES
3. Leitkam S, Bush TR *ASB, Penn State University*, 2009