A METHOD FOR PREDICTION OF SEATED SPINAL CURVATURE

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INTRODUCTION

The ergonomics of seating require knowledge of both the seat and the human that is interacting with that seat. To fully understand the interaction between these two separate bodies, it is necessary to be able to quantify and measure each. While it is possible to design and build seats that will move and conform to a wide array of spinal articulations, the ability to quantify these articulations while in a seat, such as an office chair, is still an open and unsolved problem.

Several viable methods exist for quantifying spinal curvature of some or all of the human back [1,2,3], but these primarily rely on the use of technology that is not feasible for use in an ergonomic related study. For example, X-Rays provide static images, which are not adequate for the study of dynamic seated environments. Also, the equipment required for MRI or CT scans creates an environment that is not conducive to extended seated tasks and wide ranges of movement.

The purpose of this research was to develop a method that can be used to quantify spinal articulation while seated. A future goal of this work is to utilize these methods to collect data that will support the development of a mathematical model for spinal curvature prediction in a seated environment.

METHODS

The presented method employed the use of a three-dimensional motion capture system (Qualisys, Gothenburg, Sweden) to quantify the position of visible body landmarks and used these to predict the position and orientation of the spine. Specifically, the positions of the thorax and the pelvis were measured because these two rigid bodies directly affect spinal curvature.

The relative orientations of these two structures were used to calculate an "openness" angle [4]. A larger openness angle corresponded to tilting the sternum rearward, rolling the top of the pelvis forward, and thus producing a lordotic curvature in the lumbar spine. Conversely, a smaller openness angle corresponded to tilting the sternum forward, rolling the top of the pelvis rearward, and producing a kyphotic curvature in the spine.

Six subjects with no reported back pain or spinal injuries volunteered to participate in the research. Each subject was informed of the process and signed consent to participate.

To develop the methodology and assess the relationship between "openness" and spinal articulation, all subjects were seated on a stool. While seated, the subjects were asked to assume four different static positions. Each subject was measured in maximum lordotic and maximum kyphotic lumbar positions, as well as a self-selected "natural" position and a position where the subject was asked to sit as "straight and tall" as possible. The first two were used as the extreme cases of lordotic and kyphotic postures, while the "comfortable", and "straight and tall" positions served as intermediate points within the range of normal motion.

Retro-reflective markers were affixed to each subject at key anatomical landmarks. Markers were located on the sternum, anterior superior iliac spines (ASIS), lateral femoral condyles and seventh cervical vertebra (C7), twelfth thoracic vertebra (T12), and one midway between the posterior superior iliac spines (Mid PSIS). Additionally, between C7 and T12, and between T12 and the Mid PSIS, markers were placed with a spacing of approximately 1 inch along the spinal column as seen in Figure 1.

The openness angle (θ) was calculated based on the markers affixed to the sternum, C7 and the pelvis, also seen in Figure 1. A thoracic vector was calculated with the marker on the sternum as the origin and pointing posteriorly to a marker affixed over the spinous process of the C7 vertebra. The pelvis vector was calculated with an origin at the midpoint between the right and left hip joint centers (HJC) [5] and passing through the subject's midpoint of the ASIS positions. These two vectors were then projected onto a sagittal plane and the angle between them was calculated as the openness angle.

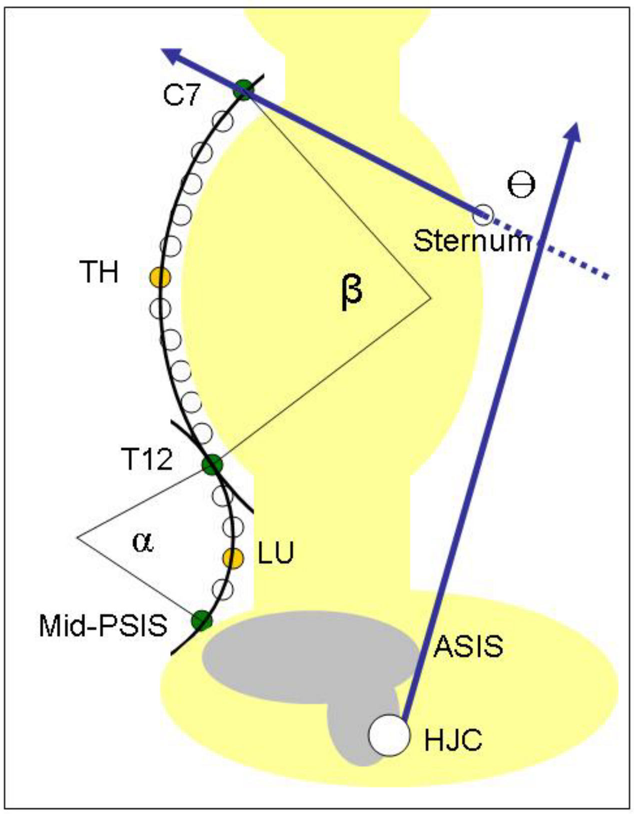

Figure 1. Definition of Curves and Angles

The curvature of the spine was quantified by two arcs. First, the primary (kyphotic) curvature was defined as an angle (β) of an arc passing through the markers at C7, T12 and the most posterior marker between the two (TH). Similarly, the secondary (lordotic) curvature was defined as an angle of an arc (α) passing through the markers at T12, Mid PSIS, and the most eccentric (anterior for lordotic curvature, posterior for kyphotic curvature) marker between those two (LU).

RESULTS AND DISCUSSION

A linear regression analysis between the openness angle and the lumbar angle across the 4 different positions, resulted in an average r^2 value for the six subjects of 0.886. An example regression plot for a single subject can be seen in Figure 2.

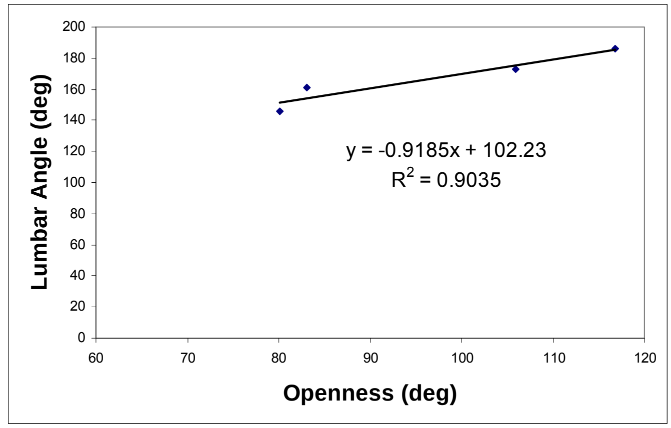

Figure 2. Sample Regression Analysis of Openness vs. Lumbar Angle for a single subject.

Figure 2 also shows the expected trend that as the openness angle gets larger, so does the lumbar angle. Physically, as the thorax tilts rearward and the pelvis rotates forward, the openness angle grows and a lordotic curvature is accentuated. Lordotic curvature corresponds with a smaller radius of curvature, and thus a larger overall angle in the lumbar region. The inverse case also holds.

CONCLUSIONS

Data demonstrated that a linear relationship existed between the openness angle and lumbar curvature. This method has the potential to be used to predict the posterior lumbar angle based on the relative positions of the thorax and pelvis. This work allows further characterization of the body seat interface on commercial seats without modification of the seat or interfering with the user/seat contact.

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