INTRODUCTION

Digital human modeling is known for its ability to help improve the speed, value, and efficiency of creating products that involve human interaction. Digital human models are used in many sectors of industry from occupant positioning and seating design to assembly line movements of workers, but developing accurate human models is challenging. These challenges largely arise from the large variations in anatomy and movement [1]. For seating in particular, understanding how spinal articulation is achieved in the seated posture as compared to the standing posture has not been well defined. Spinal curvature is impacted by a large number of factors, but as Hubbard et al. note there has not been ample research done on human spinal curvature regarding the relative rotations of the pelvis and ribcage [2]. The purpose of this research was to determine the relative influence of the ribcage and pelvis on spinal curvature in both seated and standing postures.

METHODS

The 19 subjects in this study were healthy individuals with no back pain. The subject pool consisted of eight males (average age 24.1 years, SD 2.2, range 22-27) and 11 females (average age 23.6 years, SD 1.4, range 22-26). In order to obtain spinal curvature data for seated and standing postures, a Qualisys motion capture system was used to track markers located on the subjects at key anatomical locations. Motion capture markers were placed over the seventh cervical vertebra (C7), the midway point between the two projections of the posterior superior iliac spine (MidPSIS), the sternum, the two anterior superior iliac spine (ASIS) projections and the lateral epicondyles of the femurs. Four postures were recorded: arched, erect, comfort, and slouched. These postures represented maximum kyphosis, comfortable or slight kyphosis, erect or slight lordosis, and maximum lordosis, all while maintaining a forward gaze. These postures were recorded in both the seated and standing positions.

From these data, three vectors were calculated to obtain the desired angles. The first vector started at the midpoint of the two virtually computed hip-joint centers (HJCs) and passed through the midpoint of the two ASIS markers. The second vector started at the sternum marker and passed through the C7 marker. Three angles were computed from these vectors. The first angle, $\alpha$, was a measure from the ribcage vector to a vertical reference vector (Figure 1). The second angle, $\beta$, was from the pelvis vector to the reference vector. The third angle, also known as the openness angle or $\theta$, measured the change between the ribcage and pelvis vectors. This angle change was previously linked to the amount of spinal curvature change [3].

RESULTS AND DISCUSSION

To determine the relative influence of ribcage and pelvis on the openness angle, percentages of the motion of each were calculated for both sitting and standing spinal curvature. On average, the pelvis...
produced 27% of the total openness angle change while the ribcage produced 73% of the total openness angle change. This percent distribution was the same for both the seated and standing postures. Thus, regardless of standing and sitting, the ribcage rotates approximately 2.7 times more than the pelvis when moving between maximum lordosis and maximum kyphosis. Figures 2 and 3 show the relative ribcage and pelvis angles on an individual basis.

![Figure 2: Stacked percentages comparing pelvis and ribcage relative influence on the openness angle in the standing position](image)

![Figure 3: Stacked percentages comparing pelvis and ribcage relative influence on the openness angle in the seated position](image)

The data collected in this study can also be compared on a macroscopic level in terms of the overall openness angle. Figure 4 compares the total openness angles of both seated and standing postures. The total openness angles of the two postures were similar, with the seated openness angle being slightly larger. In addition, the standard errors for the two measurements were 2.89 and 2.99 degrees for standing and seated, respectively.

![Figure 4: Comparison of the total openness angles between the seated and standing postures](image)

Additionally, when these data were analyzed for differences in gender, no statistically significance differences were identified.

**CONCLUSIONS**

In summary, this research measured the relationship of pelvis and ribcage movement in the seated and standing positions. It was found that the relative influences between the pelvis and the ribcage on spinal curvature were 27% and 73%, respectively. However, the overall range of motion, as measured by the openness angle, was larger in the seated position than the standing position. These results can be used to support the development of digital human models that mimic the appropriate ratios of ribcage and pelvis motions, and total ranges of spinal articulation in seated and standing. These findings are useful regardless of anatomical diversity and gender; however future work to look at other populations such as the elderly and obese would also be beneficial.

**REFERENCES**

3. Leitkam et al. (2011) ASME