### The Effect of Posture on Subcutaneous Adipose Tissue: A Preliminary Imaging Study

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## I. INTRODUCTION

Studies on Human Body Models (HBMs), Anthropometric Test Devices (ATDs), and Post-Mortem Human Subjects (PMHS) have identified the need to better understand the biomechanical behaviour of subcutaneous adipose tissue (SAT) in the region of the anterior superior iliac spine (ASIS) [1-3]. Although mechanical properties recently have been characterised, a knowledge gap remains in the morphology of SAT in this area with respect to bony landmarks of the pelvis. This body region is important because position of the seat belt and occupant have been found to be contributing factors in severe (Abbreviated Injury Score (AIS)3+) abdominal injuries in front crashes [4-5]. The current study builds off previous work characterising the morphology of SAT in this region using supine Computed Tomography (CT) data. The objective is twofold: First, we seek to establish correspondence between measures of SAT in matched abdominal CT and magnetic resonance imaging (MRI) scans from the same individuals in the supine posture. Next, we seek to expand that analysis by comparing data from the same individuals between supine and a seated posture.

## **II. METHODS**

A retrospective study of matched supine CT, supine MRI, and seated MRI scans (at 23 degree seatback angle) from six living subjects was conducted. The subjects represent 5<sup>th</sup>, 50<sup>th</sup>, and 95<sup>th</sup> percentile males and females and have an average body mass index of 25.16 ± 4.31 kg m<sup>-2</sup>. Images from a previous study were downloaded from the Wake Forest University Picture Archiving and Communication System, USA, under IRB00013200 [6]. Image data were loaded in Mimics v23.0 (Materialise, Leuven, Belgium) and resliced to reorient the images to the anatomical axes of the pelvis. Eleven measurements that describe SAT area, quality, and linear depth were collected from each scan (Figure 1). For scans in which the patient's size exceeded the field of view, left-right symmetry was assumed, and a half symmetry analysis was conducted to collect SAT measurements. Outcome measures were cross-plotted to compare linearity by image modality and by patient posture. Wilcoxon rank-sum tests for differences in measures ( $\alpha = 0.05$ ) were performed between all three cohorts; CT vs MRI, MRI vs. seated MRI, and CT vs seated MRI.



Fig. 1. Examplar SAT area measurement in CT, MRI and seated MRI scans.

### **III. INITIAL FINDINGS**

Every outcome measure was collected in all but three scans where visibility of the required landmarks was poor. These measures were cross-plotted to assess linearity, and Wilcoxon rank-sum tests were performed to assess significance. Slopes closer to one with small y-intercept values indicate that the two measures are very similar, and a higher R<sup>2</sup> value indicates a more linear agreement. SAT measures were found to correlate linearly between CT and MRI in the supine posture (mean slope = 0.98 and R<sup>2</sup> = 0.98), suggesting that SAT characteristics match well between these two image modalities. Only one measure, the maximum lateral diameter of the body in the SAT segmentation plane, was statistically significant when comparing image CT and MRI in the supine posture.

When analysing supine scans (CT or MRI) vs. seated MRI scans, ASIS depth measures showed a strong linear All authors with the exception of Dr. Hallman are affiliated with Wake Forest School of Medicine in Winston-Salem, NC, USA. The following authors are in the department of Biomedical Engineering: Andrea Robinson, PhD student, Austin Moore, MD/PhD student, Sam Efobi, intern, Jazmine Aira, research engineer, Scott Gayzik (sgayzik@wakehealth.edu, (1) 336-716-6643) and Ashley Weaver, Associate Professors. Leon Lenchik is in the department of Radiology. Fang Chi Hsu is in the department of Biostatistical Sciences. Jason Hallman is a senior manager at Toyota Motor North America, USA.

correlation from supine to seated posture (mean  $R^2 = 0.89$ ). While ASIS<sub>SI</sub> depth (along the vector from the sacroiliac joint to the ASIS) trends toward the identity line for scans of different modality and unchanged posture (slope = 1.0873), ASIS<sub>SI</sub> depth increases in seated posture (slope = 2.2271), and this difference was found to be statistically significant (p = 0.0313). Because of this slope, larger values of ASIS<sub>SI</sub> depth show a greater increase from supine to seated than smaller values (Figure 2).

The remaining measures showed varied results. Measures of diameter in the anterior-posterior and lateral directions as well as measures of depth at the linea alba and rectus abdominis had low R<sup>2</sup> values, slopes less than 1, and larger y-intercepts, suggesting that these measurements do not have a strong linear correlation from supine to seated posture (mean slope = 0.61 and R<sup>2</sup> = 0.48). Further, depth of SAT at the linea alba was highly sensitive to the plane at which the measurement was taken for most individuals, with some measures more than doubling when moving inferiorly or superiorly away from the initial analysis plane. SAT area showed a strong linear correlation (R<sup>2</sup> = 0.91) and slope remained unchanged from supine MRI (slope = 1.02) to seated MRI (slope = 1.01). SAT perimeter showed similar trends.



Fig. 2. Cross plots for ASIS<sub>SI</sub> (along path from sacroiliac joint) with modality comparison (left) and posture comparison (right).

#### **IV. DISCUSSION**

Cross plots of measures from supine CT and MRI show that MRI data is also a viable means to quantify SAT, since measurements between both supine modalities were nearly equivalent. The use of MRI data enables a more constitutive and structural analysis of SAT since pulse sequences can be specialized to focus on SAT in ways that go beyond the capabilities of CT. The single significant result from supine CT and MRI was attributed to the combination of a small sample size and small variance leading to statistical, but not clinical, significance. When comparing postural changes using supine and seated MRI, ASIS depth measurements were higher in seated scans while SAT area and perimeter remained the same despite changes in posture. This result, in addition to unchanged lateral measures, likely indicates a more anterior morphological rearrangement of SAT around the ASIS.

Despite the limited sample size, this study provides quantitative measures of a key design variable: the thickness of the soft tissue envelope around bony prominences of the pelvis at the level of the ASIS. The interaction with restraint systems and seat belt relative displacement may be influenced by how much soft tissue surrounds bony prominences in the body and is a particular concern in reclined positions. The results from this study highlight the shortcomings of using supine data to inform the morphology of SAT in this region of HBMs and ATDs in reclined settings and indicate a need for more data describing this area in the seated posture. Future work should focus on a greater sample size, which would allow the evaluation of sex-based differences, and further exploration of the association between outcome measures, BMI, and posture.

#### V. ACKNOWLEDGEMENTS

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# VI. REFERENCES

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