INTRODUCTION

Analysis of the forces and moments acting across the joints require several input parameters, including segment inertias (i.e. mass, center of mass location and moments of inertia). These inertias cannot be directly measured and therefore must be estimated using a body model. The accuracy of any body model is dependent on its ability to capture both the inter-individual differences and intra-individual variations in segment properties.

The more common body models used in biomechanic studies (e.g. Dempster, DeLeva, etc.) are primarily derived from the male population, though some female-specific models exist (e.g. Zatziorsky). Pregnant females are a unique population for which these traditional body models may not be appropriate, especially due to the necessary sensitivity required to capture the rapidly changing segments, primarily the trunk.

Models derived from the geometric method are most acute to capturing the rapid segment changes during pregnancy compared to models derived from other methods. The geometric-based Hatze model [1] is highly accurate but requires 133 anthropometric measures from the individual and complex algorithms not readily available. Jensen’s model [2] only requires a front and side image of the individual, from which horizontal elliptical zones 2 cm in thickness are combined to estimate segment inertial parameters. Unfortunately, the use of elliptical zones creates cavities at the segment junctions (arm-trunk and trunk-leg) that result in relatively large underestimations of the segment inertial parameters.

The Wicke trunk model [3] has used sectioned ellipses to eliminate the cavity issue and also has included non-uniform density profiles separately for the trunk of college-aged males and females. However, whether this model is capable of accurately capturing the rapidly changing morphology of the pregnant trunk has yet to be determined. This pilot study examined the sensitivity of the volume function within the Wicke model to capture these changes.

METHODS

One pregnant female 39 years of age agreed to participate in this pilot study. Testing was conducted at 17, 23, 33 and 35 weeks of her pregnancy. During each testing session, a full body scan was taken, using a 3D scanner (TC²®) that uses white light and infra-red technology resulting in approximately 1.5 million surface data points with an accuracy of within 1 mm. The participant wore a bikini to ensure accurate body surface capture. Immediately following the scan a front and side image of the participant was taken using traditional still digital cameras. Within each image, a horizontal and a vertical meter stick were captured to convert pixels to real units.

Cross sectional areas at specific heights along the trunk were calculated from the raw (object file) data of the full body scan using MatLab™. The side and front images of the participant were then digitized using the Slicer™ program. In short, this program calculates the anteroposterior and transverse dimensions at uniform intervals along the longitudinal axis of each segment. Using algorithms for geometric shapes, the volumes of each of these zones can be determined and combined with a density function to estimate the inertial parameters of each section. Where segments adjoin (e.g. hips at lower trunk & arms at upper trunk), sectioned ellipses were used to represent the cross-sectional area. At all other levels of the trunk, ellipses were adopted. The cross-sectional areas from the full...
RESULTS AND DISCUSSION

An average of 24 upper trunk and 28 lower trunk cross sections were compared for each of the four weeks during the pregnancy (Table 1). The cross sectional area of the upper trunk slightly increased during the pregnancy, by approximately 100 cm². The Wicke model was accurate at estimating the upper trunk cross-sectional area with an average error within 5%. However, at each week tested, the model over-estimated the upper trunk region and can be mainly attributed to the cavity between the breasts that cannot be captured by an ellipse (Fig.1). The model may be more accurate at capturing the contour of the breasts if a separate shape was used, as does the Hatze model.

The lower trunk region showed much greater changes in the cross-sectional area as expected; increasing by approximately 250 cm². The model was more accurate at capturing this region compared to the upper trunk. At the 33rd week, the error was slightly greater than the other weeks. It is not certain why this happened, but could be simply due to the errors caused during the manual digitization process.

Overall, the volume function of the Wicke model appears to accurately capture the changes in the trunk region during pregnancy. However, the model needs to be tested on a greater sample to be more conclusive with the above statement. In addition, the overall error for the trunk inertial estimates during pregnancy has yet to be established. There are regions of over-estimation that counterbalance regions of under-estimation within the volume function. In addition, the density function will introduce further error, though the accuracy of geometric models are much more sensitive to the volume function compared to the density function [4].

The intra-individual changes that occur during pregnancy require adaptations in movement and the intersegmental moments concomitant to these inertial changes. In turn, proper adjustments to physical activities, equipment and other factors related to the pregnant female can be made to minimize the challenges that are faced during this period. The Wicke model shows potential for capturing

Table 1: Mean ± SD of cross sectional areas (cm²) and error (%) of the Wicke model for the upper and lower trunk.

<table>
<thead>
<tr>
<th>Week</th>
<th>Upper Trunk</th>
<th>Lower Trunk</th>
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<tbody>
<tr>
<td></td>
<td>3D</td>
<td>Wicke</td>
</tr>
<tr>
<td>17</td>
<td>668.5 ± 134.6</td>
<td>637.8 ± 126.9</td>
</tr>
<tr>
<td>23</td>
<td>772.6 ± 135.2</td>
<td>738.8 ± 131.0</td>
</tr>
<tr>
<td>33</td>
<td>784.1 ± 148.1</td>
<td>770.5 ± 136.2</td>
</tr>
<tr>
<td>35</td>
<td>752.0 ± 126.1</td>
<td>703.1 ± 130.8</td>
</tr>
</tbody>
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REFERENCES