Psoas Muscle Attachment Location Prediction from Clinical Measurement in Children and Adults

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Introduction

Many biomechanical methods require the use of three-dimensional anthropomorphic data and are typically based on average adult anatomy. This introduces inaccuracies, particularly in children because of the growth changes in long bone geometry. As locomotor models become more sophisticated, the need for accurate musculo-skeletal data increases. For example, the calculations of muscle lengths, forces and lever arms rely on accurate estimates of muscle attachment co-ordinates.

It is now possible to produce subject specific models from Magnetic Resonance Imaging (MRI) (Gefen et al., 1998; Jorgensen et al., 2001, Arnold et al., 2001). However, for routine clinical application more general customisation techniques are required. In this study we investigate femoral anteversion and age as predictors of the location of the psoas muscle attachment in healthy adults and children.

Methods

Femoral anteversion was determined in 15 healthy volunteers (ages 5 – 48) and 5 children with cerebral palsy (ages 6-11) by external clinical examination (Ruwe et al., 1992), and from MRI scans using a common clinical protocol (Wiener, 1978). The two methods were then compared for consistency.

Psoas muscle attachment locations on the femur were detected for 12 of the children and 5 of the adults. Bone-embedded co-ordinate systems were established from T1-weighted three-dimensional gradient echo MRI scans of the femur (fig. 1). Psoas muscle attachment centroids were detected manually using medical imaging software (Analyze, B.I.R., MN). The coordinates of each centroid were then normalised to the length of the femur. This technique was validated by comparison with cadaveric dissection in a parallel study. The correlations of the muscle attachment location with age and with femoral anteversion were examined using Pearson’s correlation coefficient.

![Figure 1: Bone embedded co-ordinate system, XYZ, defined as shown for the right femur, with unit vectors](image)

\[
\begin{align*}
K &= \text{LEP} - \text{MEP} / ||\text{LEP} - \text{MEP}||, \quad I = (\text{GTRO} - \text{LEP}) / ||\text{GTRO} - \text{LEP}|| \times K, \quad J = K \times I.
\end{align*}
\]
Results

Regression analysis gave a direct relationship between externally measured femoral anteversion ($F_1$), and the femoral anteversion calculated from MR images ($F_2$), ($F_2 = F_1 + 3^\circ$, Standard Error = 4.4$^\circ$).

Figure 2 shows the relationship between externally measured femoral anteversion and psoas muscle attachment coordinates. Correlation of these coordinates with age and femoral anteversion in all three directions for both children and adults is presented in Table 1.

<table>
<thead>
<tr>
<th>Psoas Coordinates</th>
<th>Correlation with Age</th>
<th>Correlation with femoral anteversion</th>
</tr>
</thead>
<tbody>
<tr>
<td>X (anterior-posterior)</td>
<td>-0.7</td>
<td>0.8</td>
</tr>
<tr>
<td>Y (cranio-caudal)</td>
<td>0.5</td>
<td>-0.7</td>
</tr>
<tr>
<td>Z (medio-lateral)</td>
<td>0.6</td>
<td>-0.7</td>
</tr>
</tbody>
</table>

Table 1: Correlation of muscle attachment coordinates with age and externally measured femoral anteversion. Coordinates were calculated as % femoral length.

Figure 2: Relationship between femoral anteversion and psoas muscle attachment coordinates in X, Y and Z directions (as defined in figure 1.) Cerebral palsy subject data, marked by *, shown for comparison.
Discussion

Femoral anteversion shows a higher correlation with muscle attachment
Bone geometry is not entirely determined by age; there are individual variations in anatomy and development rate, so an objective measure of geometry is required. The use of femoral anteversion to predict musculo-skeletal anatomy could increase accuracy in the biomechanical analysis of muscle lengths and forces in children and adults.
Femoral anteversion directly affects the position of the femoral muscle attachments in the transverse (XY) plane of the femur. The relationship between femoral anteversion and the Y coordinates may be due to a discrepancy between the orientation of the y-axis and the plane in which femoral anteversion occurs. A further factor is the relationship between femoral anteversion and femoral neck angle, introduced by the normalisation. The linear relationships that are apparent suggest femoral anteversion to be a reliable external measurement that can be used to predict psoas attachment locations. This allows for the possibility of a future musculo-skeletal model to be routinely adapted to the individual without the need for invasive or expensive measurements.
Similar analysis is being extended to additional femoral muscle attachments and the attachments on other bones. It is also being extended to children with cerebral palsy (figure 2) who are a typical patient group that undergo clinical gait analysis; femoral anteversion is usually increased in this group and would therefore have a greater impact on modelling inaccuracies.

References

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