AGE-RELATED DIFFERENCES IN TRUNK KINEMATICS OF TYPICALLY-DEVELOPING CHILDREN DURING GAIT

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SUMMARY
The trunk kinematics during gait of 58 typically-developing children aged 4-16 years were analysed. They showed that the range of motion of the trunk decreased with age in all three planes. The pattern of movement in the sagittal and transverse planes was consistent across the age groups, however the coronal plane data were more variable. The inter-subject variability appeared to be higher in the younger age groups across all three planes. This confirms the need to use age-matched controls in trunk motion analysis since there are differences in trunk kinematics across the childhood age spectrum.

INTRODUCTION
The lower limb kinematics of gait are known to generally reach a mature pattern by 4 years of age, although intra- and inter-subject variability is still increased at this age [1]. There has been little published data regarding trunk kinematics. Standards governing gait laboratories in the UK recommend that reference data is age-matched [2] but it is important to understand how kinematic data change with age in order to appropriately compare to pathological gait.

The Oxford Trunk Model was developed to allow routine clinical analysis of trunk kinematics during gait and has been shown to have comparable variability and pattern to other established models [3]. From a clinical perspective, the advantage of this model is that female subjects may wear a strappy vest top during data collection, with just the back rolled up to T12 level for the static trial. This improves subjects’ comfort and therefore allows routine analysis of trunk motion during routine clinical gait assessment.

METHODS
Data on 58 typically-developing children were collected as part of a project to compile a complete set of reference gait data for clinical use. The children were aged between 4 years 11 months and 16 years 7 months (mean 10 years 0 months); there were 37 girls and 21 boys. They were asked to walk at self-selected speed and a representative trial was selected for analysis. Data were collected using a 12 camera Vicon MX System (Oxford, UK) sampling at 100hz and were processed using the Nexus software (Vicon, Oxford, UK).

The Oxford Trunk Model (OFM) uses markers on the 2nd, 6th and 12th thoracic vertebrae and the clavicular notch. The marker on the 12th thoracic vertebra is used in the static trial only to calculate an offset in the sagittal plane which has been shown to improve inter-subject variability [1]. Movement in the sagittal, coronal and transverse planes is respectively described as flexion, lateral flexion and rotation and is calculated relative to the global co-ordinates.

For each subject, the mean and range of the trunk flexion, lateral flexion and transverse rotation was calculated for a left gait cycle. Linear regressions of the six trunk parameters and age were calculated using SPSS, v.16 (IBM, NY, USA)

Data were also grouped into four age categories (4-6, 7-9, 10-12 and 13-16 years) with 15 subjects in each group, except for the oldest group which contained 13 subjects. The group data was qualitatively plotted and assessed for changes in pattern and variability.

RESULTS AND DISCUSSION
Analysis of the effect of age on the mean trunk parameters shows that the range of motion in all three planes decreases significantly with age (Figure 1).

The mean trunk kinematics of the different age groups (Figure 2) show that in the sagittal and transverse plane, the pattern is similar for all age groups suggesting that in the youngest age group, the mature gait pattern has already been achieved. In the coronal plane, the pattern appears to be more variable across the age groups. This could be due to the small range of motion in this plane or the effect on the results that a small misplacement of either the T2 or T6 markers could have due to their role in defining the primary axis.

Visually, there appears to be a wider inter-subject variation in trunk kinematics in the sagittal and transverse planes for the younger age groups (Figure 2). Table 1 supports this as the inter-subject standard deviation for flexion and rotation is higher in the younger age groups than the older ones. However, when looking at the coefficients of variation for the ranges of trunk kinematics in each age group (Table 2), there is little difference between the groups, suggesting that the variation in range is no higher in the younger age groups than the older ones.

The increased inter-subject variability in younger children may reflect incomplete maturation of gait and balance. The increased range of trunk motion in younger children may represent a balance reaction, also reflecting immaturity.


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Figure 1: Plots of range of movement in each plane versus age. Line shown is the trendline; $R^2$ and $p$-values are shown at top of graphs.

<table>
<thead>
<tr>
<th>age group</th>
<th>Mean Flexion</th>
<th>Mean Lateral Flexion</th>
<th>Mean Rotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-6</td>
<td>7.04 ± 6.67</td>
<td>1.70 ± 4.24</td>
<td>-0.21 ± 5.91</td>
</tr>
<tr>
<td>7-9</td>
<td>5.86 ± 5.83</td>
<td>0.03 ± 3.43</td>
<td>1.69 ± 3.79</td>
</tr>
<tr>
<td>10-12</td>
<td>6.91 ± 4.56</td>
<td>1.20 ± 1.21</td>
<td>2.61 ± 3.92</td>
</tr>
<tr>
<td>13-16</td>
<td>7.33 ± 4.06</td>
<td>1.34 ± 3.05</td>
<td>0.43 ± 3.20</td>
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</tbody>
</table>

Table 1: means and standard deviations (s.d.) of mean trunk kinematics for each age group

<table>
<thead>
<tr>
<th>age group</th>
<th>Range Flexion</th>
<th>Range Lateral Flexion</th>
<th>Range Rotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-6</td>
<td>6.61 ± 0.37</td>
<td>5.91 ± 0.57</td>
<td>11.24 ± 0.39</td>
</tr>
<tr>
<td>7-9</td>
<td>5.87 ± 0.38</td>
<td>5.31 ± 0.45</td>
<td>7.41 ± 0.42</td>
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<tr>
<td>10-12</td>
<td>4.38 ± 0.30</td>
<td>3.08 ± 0.40</td>
<td>7.17 ± 0.34</td>
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<tr>
<td>13-16</td>
<td>4.48 ± 0.37</td>
<td>3.92 ± 0.63</td>
<td>6.81 ± 0.32</td>
</tr>
</tbody>
</table>

Table 2: means and coefficients of variation (cv) of trunk kinematic ranges for each age group

CONCLUSIONS
Trunk kinematics in typically developing children change with age. In particular, the range of trunk motion in all three planes decreases with age. The inter-subject variability also appears to decrease with age. When assessing pathological gait and, particularly, trunk motion, in children, it is important to use age-matched normal data in order to avoid interpreting differences due to age as pathology.

REFERENCES
2. CMAS (UK). Clinical Gait Analysis Standards 2010 (version 4)