Errors in the Calculation of the Hip Joint Centre Location in Children

S. E. M. Jenkins¹, M. E. Harrington², A. B. Zavatsky¹, T. N. Theologis², J. J. O'Connor¹
²The Oxford Gait Laboratory, Nuffield Orthopedic Centre, Oxford/U.K.

Introduction

The location of the hip joint centre (HJC) is commonly derived during gait analysis. The HJC gives the location about which hip moments are calculated and is often used to determine the location and orientation of the femur. Errors in the calculation of the HJC are therefore propagated down the limbs through kinematic and kinetic calculations.

Clinical gait analysis is predominantly used for the assessment of children. However, the most common technique of estimating HJC is by algorithms derived from average adult anthropometric data. This may not be appropriate for juvenile subjects whose pelvic geometry is still maturing, and even less so for children with cerebral palsy who, almost invariably, have musculo-skeletal deformities. Previous studies have compared the error in HJC estimation by different techniques in living (Alderink et al., 2000, Leardini et al., 1999) and cadaveric (Seidel et al., 1995) adult specimens. Fieser et al. (2000) recently highlighted the need to re-examine the HJC location prediction techniques that are applied to children.

This work aims to assess a typical prediction technique for the HJC, and to quantify the errors involved in its application to adults and children.

Methods

Three-dimensional gradient echo magnetic resonance imaging (MRI) scans of the pelvis were taken of 5 adults (ages 23-40) and 15 children (ages 5-12) including 5 children with cerebral palsy. These scans were used to locate the co-ordinates of palpable bony landmarks including the anterior and posterior superior iliac spines, and of the HJC, which was taken as the centre of a sphere fitted to the femoral head. The HJC was then calculated from the position of the landmarks and leg length using a predictive algorithm that is frequently applied in gait analysis (Davis et al., 1991). Both HJC results were compared for each subject to give an estimate of error, which was related to age.

![Figure 1: Pelvis, demonstrating anatomical landmarks and embedded co-ordinate system, X, Y and Z are defined in accordance with ISB guidelines.](image)

The accuracy of the MRI measurements was validated, in a parallel study, using a cadaveric specimen.
Results
Error is defined as the discrepancy between result calculated by applying the Davis et al. (1991) algorithm and location obtained directly from MRI. Mean errors, with standard deviations, are given in Table 1. Figure 2 shows the errors plotted as % ASIS width, to illustrate the magnitude of errors in relation to the size of the subjects.

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Resultant error (mm)</th>
<th>Error in X (mm)</th>
<th>Error in Y (mm)</th>
<th>Error in Z (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>18+: n=6</td>
<td>17 (6)</td>
<td>-11 (7)</td>
<td>2 (2)</td>
<td>9 (7)</td>
</tr>
<tr>
<td>10-12: n=4</td>
<td>23 (8)</td>
<td>-10 (10)</td>
<td>9 (3)</td>
<td>16 (9)</td>
</tr>
<tr>
<td>7-9: n=4</td>
<td>23 (11)</td>
<td>-13 (12)</td>
<td>6 (8)</td>
<td>15 (9)</td>
</tr>
<tr>
<td>5-6: n=4</td>
<td>20 (7)</td>
<td>-18 (6)</td>
<td>2 (2)</td>
<td>8 (7)</td>
</tr>
<tr>
<td>Cerebral Palsy</td>
<td></td>
<td></td>
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<tr>
<td>6-11: n=5</td>
<td>55 (23)</td>
<td>-16 (16)</td>
<td>29 (24)</td>
<td>40 (8)</td>
</tr>
</tbody>
</table>

Table 1: The mean differences are quoted, with standard deviations given in brackets. Axes are defined as shown in figure 1.

Figure 2: Variation of Absolute Error in HJC location with age, where ♦ = subjects with cerebral palsy and ♠ = normal subjects.
**Discussion**

HJC estimations based on algorithms such as those used in commercial gait analysis packages can result in large misallocations in adults. The errors in adults observed here are in agreement with those previously published (Leardini et al., 1999). This technique is regularly applied clinically to children as young as five years old, despite resultant errors as large as 40 mm in one case. In children with cerebral palsy and associated musculo-skeletal deformity, an individual resultant error reached 85 mm. The greatest errors were seen in the anterior-posterior direction, and these appeared to decrease with age, until skeletal maturity. Although statistically the sample was not large enough to give a significant regression between the different ages examined, errors were shown to be significantly higher in healthy children than adults (p = 0.01).

Stagni et al. (2000) showed that errors in the range of only 30 mm in HJC caused 22% errors in hip moment, and 25% errors in flexion extension timing. Therefore, when applied to children, gait models using this technique will cause large inaccuracies in the gait analysis results.

The consistent bias shown by the mean errors across the age groups implies that there is scope for improvement of the algorithms tested. However, the spread of data demonstrated by the standard deviations suggests that an alternative approach might be necessary.

**References**


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