Prediction of the hip joint centre in adults, children, and patients with cerebral palsy based on magnetic resonance imaging

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Abstract

The location of the hip joint centre (HJC) is required for calculations of hip moments, the location and orientation of the femur, and muscle lengths and lever arms. In clinical gait analysis, the HJC is normally estimated using regression equations based on normative data obtained from adult populations. There is limited relevant anthropometric data available for children, despite the fact that clinical gait analysis is predominantly used for the assessment of children with cerebral palsy. In this study, pelvic MRI scans were taken of eight adults (ages 23–40), 14 healthy children (ages 5–13) and 10 children with spastic diplegic cerebral palsy (ages 6–13). Relevant anatomical landmarks were located in the scans, and the HJC location in pelvic coordinates was found by fitting a sphere to points identified on the femoral head. The predictions of three common regression equations for HJC location were compared to those found directly from MRI. Maximum absolute errors of 31 mm were found in adults, 26 mm in children, and 31 mm in the cerebral palsy group. Results from regression analysis and leave-one-out cross-validation techniques on the MRI data suggested that the best predictors of HJC location were: pelvic depth for the antero-posterior direction; pelvic width and leg length for the supero-inferior direction; and pelvic depth and pelvic width for the medio-lateral direction. For single-variable regression, the exclusion of leg length and pelvic depth from the latter two regression equations is proposed. Regression equations could be generalised across adults, children and the cerebral palsy group.

Keywords: Gait; Hip joint centre; Motion analysis; MRI; Cerebral palsy

1. Introduction

In gait analysis, the hip joint centre (HJC) is the point about which hip moments are calculated, and it is often used in determining the location and orientation of the femur and in estimating the lengths and lever arms of muscles crossing the hip. Unlike prominent bony landmarks, such as the superior iliac spines, the HJC cannot be palpated and thus its location must be calculated. Errors in the location of the HJC can propagate down the limbs through kinematic and kinetic calculations.

Although clinical gait analysis is predominantly used for the assessment of children with cerebral palsy, the most common ways of estimating HJC rely on equations derived from average adult anthropometric data. These may not be appropriate for children, whose pelvic geometry is still maturing, and even less so for children with cerebral palsy who, almost invariably, have musculoskeletal deformities.

Previous studies found the error in HJC estimation in adults using a range of methods in living subjects (Kirkwood et al., 1999; Leardini et al., 1999) and cadaveric specimens (Seidel et al., 1995). Functional techniques, such as those proposed by Cappozzo (1984),...
following single linear regression equations (in mm) are proposed for the right hip:

\[
\hat{x} = -0.24PD - 9.9, \tag{5}
\]

\[
\hat{y} = -0.30PW - 10.9, \tag{6}
\]

\[
\hat{z} = 0.33PW + 7.3. \tag{7}
\]

Results in this study indicate that these could improve estimates based on existing predictive methods by up to 7 mm, depending on method and direction considered. However, predictive methods do not account for pelvic asymmetry, which was found to average 6 mm in this study, and do not account for errors in marker placement or skin movement artefacts.

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References


