Accuracy of a Functional Method of Locating the Joint Center of the Abnormal Hip:  
A Validation Study using MRI  
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Introduction: In most gait laboratories, the location of the hip joint center (HJC) is primarily  
obtained using predictive methods, which fail to account for between-subject variability or hip  
pathology [1]. Alternatively, the functional method, which involves locating the center of  
rotation between the femur and pelvis by fitting a sphere to the trajectory of a thigh fixed  
marker, has been found to be more accurate than predictive approaches in locating the centers  
of patient-specific hip joints [2], even when hip motion is limited [3]. Hence, the purpose of  
this study was to compare the accuracy of the functional method to that of a predictive  
approach in locating the joint centers of abnormal hips relative to their true locations  
confirmed through magnetic resonance imaging (MRI).

Statement of Clinical Significance: If the functional method is found to be more accurate  
than a predictive approach in locating the hip joint center of the abnormal hip, then the  
utilization of this method will minimize location errors known to adversely affect gait analysis  
results and subsequent planning for treatment of hip pathologies [4].

Methodology: Subjects: Three patients with unilateral hip pathology were consented and  
studied for this report. Two patients (Subjects 1 & 3) were diagnosed with unilateral Legg-  
Calve-Perthes (LCP) disease and one patient (Subject 2) with unilateral hip dysplasia (DDH).  
Experimental Procedure: Each patient underwent a MRI procedure as part of their routine  
clinical care. Vitamin E capsules (0.5 cm wide) were placed over surface marks overlying the  
two anterior superior iliac spines (ASIS) and the sacrum. The centers of the normal and  
affected hip joints were located relative to a pelvic coordinate system defined by these capsule  
positions. Gait analysis data were then collected using an eight camera motion analysis  
system (Motion Analysis Corp., Santa Rosa, CA) that captured the trajectories of 2.5 cm  
reflective markers placed over the identical pelvic marks and over twelve anatomical points  
defining the thigh, shank, and foot segments as well as the knee and ankle joints.  

Data analysis: The HJC locations on both the normal and affected sides were estimated using  
predictive and functional methods. The predictive method involved expressing the HJC as  
percentages of pelvic width along the x (anterior-posterior), y (medial-lateral), and z  
(superior-inferior) axes of the pelvic coordinate system using the default values in the  
Orthotrak software (Motion Analysis Corp.). The functional method was implemented by  
finding a set of HJC coordinates and sphere-fit radii that minimizes the error function  
described by Shea et al. [5]. The coordinates and radius determined from “sphere-fitting” the  
trajectory of the thigh marker were used as initial guesses for the minimization process  
repeated with the trajectory of the knee marker. The entire process was executed using the  
Nelder-Mead simplex model of the fminsearch function available in MATLAB (Mathworks,  
Inc., Natick, MA). Marker trajectories were taken from bilateral hip motion during walking  
alone (FW) and during a combination of hip flexion-extension, abduction-adduction, and  
circumduction within the subject’s range-of-motion (ROM) limits (FC).

Results: Errors were calculated as the absolute distance between the estimated and the MRI  
determined HJC locations and are listed in Table 1. The errors were smallest when the  
functional method was implemented with combined hip ROM (FC) with the exception for
Subject 3, who was unable to abduct or circumduct the affected hip. Larger errors were found with the predictive approach followed by the functional method executed from walking (FW), which was most accurate only in the anterior-posterior direction as demonstrated in Figure 1.

Table 1: Errors (mm) in Functional vs. Predictive HJC Locations (FC = functional method based on combined hip ROM, FW = functional method based on walking)

<table>
<thead>
<tr>
<th>Subject (Dx)</th>
<th>Normal Side</th>
<th>Affected Side</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FC</td>
<td>FW</td>
</tr>
<tr>
<td>1 (LCP)</td>
<td>9.6</td>
<td>113.4</td>
</tr>
<tr>
<td>2 (DDH)</td>
<td>18.5</td>
<td>44.3</td>
</tr>
<tr>
<td>3 (LCP)</td>
<td>19.6</td>
<td>48.6</td>
</tr>
</tbody>
</table>

* - Functional method failed to converge on a minimum error for this motion

Figure 1: Functional, Predictive, and MRI HJCs for Subj. #1 (mm) (gray area = affected side)

Transverse Plane          Frontal Plane

**Discussion:** The functional method was least accurate in locating the HJC in the medial-lateral and superior-inferior directions when hip motion was predominantly hip flexion-extension, as seen in walking and in the hip ROM on the affected side of Subject 3. However, this study has shown that the functional method is more accurate than the predictive approach as long as there is hip motion in all three planes even when motion is limited in these directions, contrary to previous suggestions [6]. Therefore, the functional method would be more applicable than a predictive approach in locating the center of an abnormal hip joint.

**References:**

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