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-Meed 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

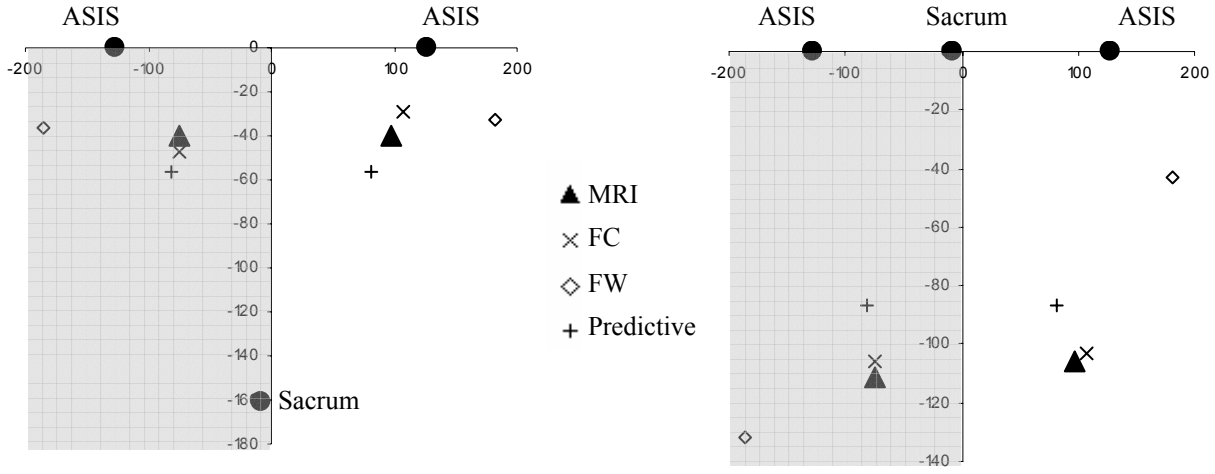
Subject 3, who was unable to abduct or circumduct the affected hip. Larger errors were found with the predictive approach followed by the functional method executed from walking (FW), which was most accurate only in the anterior-posterior direction as demonstrated in Figure 1.

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

Subject (Dx)	Normal Side			Affected Side		
	FC	FW	Predictive	FC	FW	Predictive
1 (LCP)	9.6	113.4	30.8	14.5	104.9	30.3
2 (DDH)	18.5	44.3	31.9	18.7	67.4	47.9
3 (LCP)	19.6	48.6	40.6	71.8	*	31.8

* - 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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