The Reliability of Two Dynamic Methods for Hip Joint Center Estimation

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Introduction: The location of the hip joint center (HJC) plays a vital role in determining lower extremity kinematics and kinetics. Errors in HJC location propagate "downstream" to all distal joints/body segments. For this reason, accurate, objective and repeatable HJCs are essential to high-fidelity gait analysis. The traditional method for HJC estimation is based on anthropometric regression equations, palpated landmarks, measured anatomical dimensions and manually placed markers. The systematic and random errors inherent in this methodology have been measured in detail [1]. Several dynamic methods of HJC estimation exist, including the functional method [2] and the kinematically constrained method [3]. The functional method defines the HJC as the origin of a sphere of best fit. The kinematically constrained method defines the HJC as the intersection of all instantaneous axes of rotation of the thigh relative to the pelvis. The functional and kinematically constrained methods have been shown to be superior to traditional methods in terms of accuracy, objectivity and repeatability [1,4,5]. In this study, we compare the HJC estimates derived with the functional and kinematically constrained methods.

Statement of Clinical Significance: Accurate and objective hip joint center estimates can be obtained using either the function or kinematically constrained method. The KC produces a significantly more reliable HJC estimate, and is therefore more useful in a clinical setting.

Methodology: A single subject was tested by four different physical therapists. The tests were performed on different days to ensure that no trace of palpation, measurement or marker placement remained. For each test, the subject donned 14 mm reflective markers on the pelvis and thighs. Pelvic markers were placed on the mid point of the posterior-superior iliac spine (PSIS) and on each anterior-superior iliac spine (L/R ASIS). Thigh markers consisted of a lateral wand mounted marker, a skin mounted marker on the anterior thigh and bi-condylar markers. The subject performed a series of 10 consecutive bilateral simultaneous hip circumduction trials ("hula-hoop" motion). Marker trajectories were captured using a 12 camera Vicon 512 system (Oxford Metrics, Oxford, England). HJC estimates were then computed for the trials using the functional and kinematically constrained methods.

Table 1

			KC	Functional
Hip Joint Center	Ant/Pst	Mean	61.6	51.1
		Std Dev	1.1	2.3
		Range	10.2	20.6
	Med/Lat	Mean	90.1	92.0
		Std Dev	1.9	2.0
		Range	17.2	18.8
	Sup/Inf	Mean	99.7	115.5
		Std Dev	1.6	5.5
		Range	15.0	53.3

Results: The pelvic coordinate system used to report the estimated HJC follows the standard clinical definition: The origin is at the mid point of ASIS markers. The lateral direction points from the origin to the L-ASIS. Anterior is directed from the PSIS marker to the origin, perpendicular to the lateral direction. The superior direction is perpendicular to the plane that contains

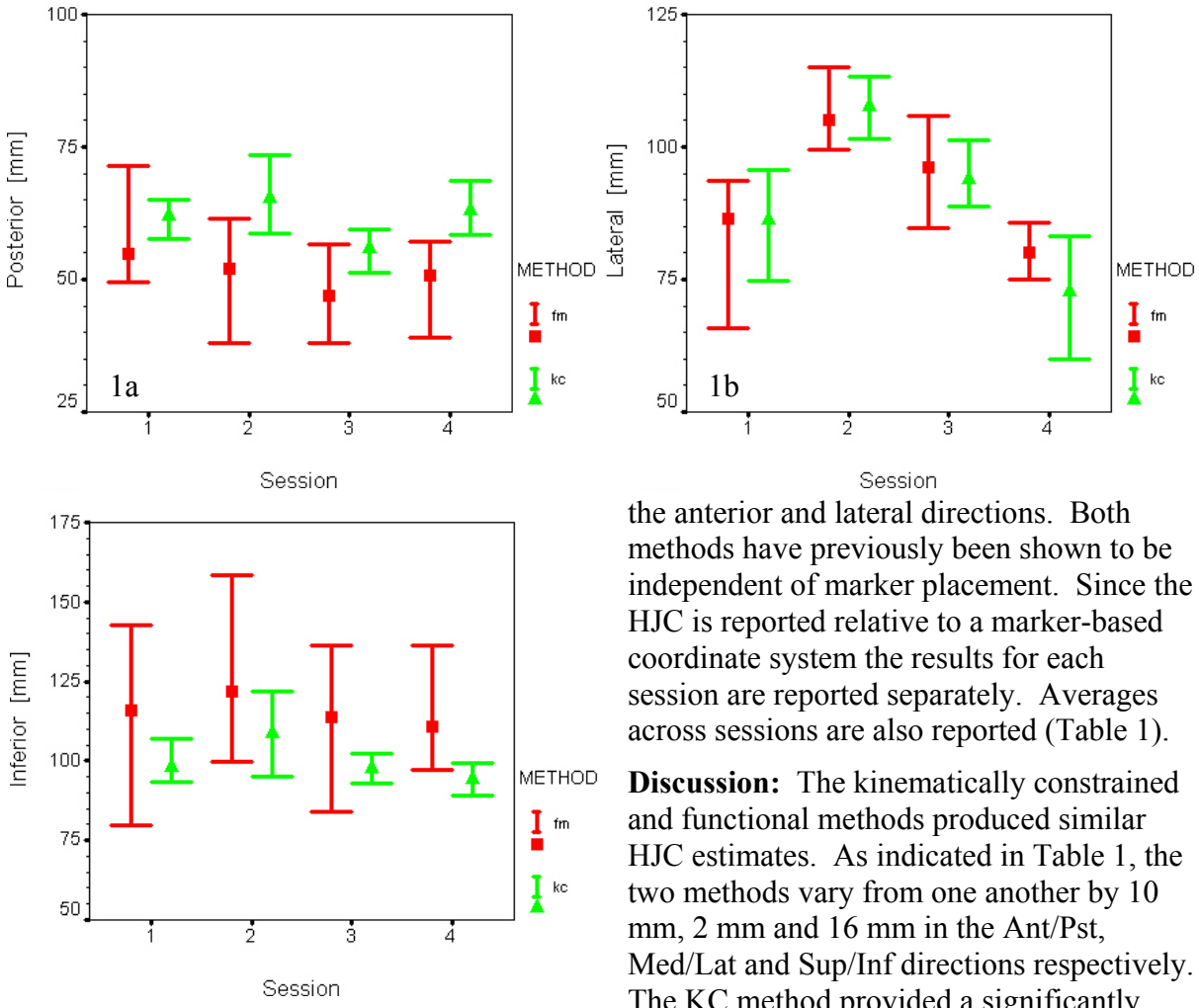

Figure 1a-1c. The mean HJC estimates are displayed along with the maximum and minimum values obtained over the 10 trials.

the anterior and lateral directions. Both methods have previously been shown to be independent of marker placement. Since the HJC is reported relative to a marker-based coordinate system the results for each session are reported separately. Averages across sessions are also reported (Table 1).

Discussion: The kinematically constrained and functional methods produced similar HJC estimates. As indicated in Table 1, the two methods vary from one another by 10 mm, 2 mm and 16 mm in the Ant/Pst, Med/Lat and Sup/Inf directions respectively. The KC method provided a significantly greater degree of reliability than the functional method as assessed by the standard deviation and range of the HJC estimate. This was particularly evident in the Ant/Pst and Sup/Inf directions, where the KC method exhibited ½ - ¼ the variation of the functional method. In the Med/Lat direction the two methods were virtually identical. The functional method has been shown to be more accurate and more objective than the standard clinical approach [1,4,5]. However, concerns have been raised regarding the repeatability of the functional method [6]. The KC method provides a practical, accurate, objective and repeatable means for estimating the HJC. To date, the KC method has been applied to healthy subjects. The method is currently being applied to patients with a variety of pathologies. Preliminary results indicate that the method is equally applicable, practical and repeatable in these subjects.

References:

1. Leardini A et al. J Biomech, 32:99-103, 1999. **2.** Cappozzo A, Hum Mov Sci 3:27-54, 1984. **3.** Schwartz MH and Rozumalski A, Gait Posture 16:S95-6, 2002. **4.** Schwartz MH and Rozumalski A, Gait Posture 16:S63-4. **5.** Schwartz MH and Rozumalski A, Gait Posture 16:S174, 2002. **6.** McDermott et al. Gait Posture, 14:181, 2001.