Determining the best hip joint centre localization method for normal subjects compared to the EOS system – Preliminary results

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SUMMARY

The purpose of this work was to establish the accuracy of various conventional and functional methods to locate the Hip Joint Center (HJC) in the context of gait analysis. The methods HJC were compared with EOS, a low dose bi-plane X-ray device, images. Various parameters of the hip functional trial were investigated: self performed or assisted movement, natural or small Range of Movement (ROM) and marker sets on the thigh. The preliminary results shows that for the self performed natural ROM the best functional calibration technique was from the sphere fitting family with an accuracy of 15(5)mm. The best conventional method gave an accuracy of 20(8)mm. These results should be confirmed upon analysis of the whole dataset and for all configurations. It should provide a comprehensive comparison of available methods for HJC localization in research and clinical use.

INTRODUCTION

In motion analysis, bone and joint positions are deduced from external marker positions. The conventional way to determine the position of the HJC in clinical gait analysis is to use regression equations that define the position of the hip from the patient anthropometric measurements and pelvis markers. A different approach uses functional calibration to locate joint centers in relation to the tracking markers. With this methodology, joint center positions should mainly depend on segments relative movement and not on absolute marker placement. Although the accuracy of such methods has been previously reported 0, recent developments made by the two approaches [3, 4 and 5] justify an update on their respective strength. This study assessed the HJC localization accuracy with reference to the EOS® (EOS imaging, Paris, France) data on a normal population implementing a state of the art of the methods available.

HJC localization is one of the main modeling assumptions made in gait analysis. Finding the optimal method to make this assumption and knowing its accuracy for a given population is therefore of great importance.

METHODS

24 adults participated in the study. They were of various body mass indexes ranging from 17 to 33. Plug In Gait (PIG), (VICON, Oxford, UK) and Harrington et al. [3] were used as the conventional way to determine the HJC location from regression equations.

For the functional calibration the subjects were equipped with 4 markers on the pelvis (Left/Right and Anterior/Posterior Superior Iliac Spine) and 3 or 6 markers on each thigh. The calibration exercises consisted of 5, star shaped, movements: hip flexion, hip extension, hip abduction, hip flexion and abduction and hip extension and abduction. The subjects were instructed to perform the calibration exercises as they prefer, without looking for the maximum ROM (natural) or for a small ROM (~15°). The movements were self performed or assisted leading to 4 different functional movements. Three types of functional calibration techniques were implemented: Sphere fitting, Transformation and Global calibration techniques. Two sphere fitting techniques, Geometrical [7] and Algebraic [8], and 2 transformation techniques, CTT and SCORE [4], were tested. For the sphere fitting and transformation techniques the segment movement was determined by the least squares mapping [6] of the skin mounted markers. The global calibration technique, called Kylie, is a new method provided by VICON to be evaluated in a clinical environment.

Prior to the motion analysis, all the subjects had an EOS scan of their lower limb. All the markers, visible on the EOS images, were localized by fitting 14mm spheres on the 2 EOS images. This allowed the registration of the femoral heads in the pelvic coordinate system as defined by the motion analysis models.

RESULTS AND DISCUSSION

Preliminary results were obtained for 13 subjects from the total set. The self performed movement and natural ROM was used for these preliminary results.

The results (Table 1) showed that the functional Algebraic sphere fitting technique had the best accuracy. Of the conventional methods, PIG performed poorly but the Harrington et al. regression equations results were closer to the best functional calibration methods. The proportion of the sample with error greater than a chosen threshold was also investigated. These indicated the two functional sphere fitting were never further than 25mm from the EOS reference. For the transformation techniques, increasing the number of markers on the thigh segment gave better results whereas for the sphere fitting techniques it had almost no effect. The new global calibration method gave results similar to the functional transformation techniques.

On the sample studied in this work, the first functional calibration method described in the literature, Geometrical [7], gave better results than any of the newly developed algorithms. The best conventional method was the latest one, with regression equations deduced from a large population of adults and children.

These preliminary results should be confirmed once the whole set of subject is analyzed. The small ROM and passive ROM also need to be analyzed in order to derive HJC accuracy results that encompass the various use of conventional and functional HJC calibration in research and clinical use.

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Table 1: Differences between EOS and model determined 3-D HJC location

		Descriptive Statistics mm		Proportion of sample with error > threshold (mm) in %		
Model		Mean	SD	> 20	> 25	> 30
Conventional	Plug in Gait	26	10	77	54	31
	Harrington	20	8	54	23	8
Functional (3 Markers)	Geometrical	15	5	15	0	0
	Algebraic	15	5	8	0	0
	CTT	21	8	54	38	15
	SCORE	21	8	54	38	15
	Global	23	12	54	46	23
Functional (6 markers)	Geometrical	16	5	8	0	0
	Algebraic	15	5	15	0	0
	CTT	18	7	23	15	8
	SCORE	18	7	23	15	8