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Short communication

Verification of an improved hip joint center prediction method

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ABSTRACT

In motion analysis, the hip joint center (HJC) is used to define the proximal location of the thigh segment and is also the point about which hip moments are calculated. The HJC cannot be palpated; its location must be calculated. Functional methods have been proposed but are difficult to perform by some clinical populations. Therefore, regression methods are utilized, but yield large errors in estimating the HJC location. These prediction methods typically utilize the anterior and posterior superior iliac spines, where excessive adipose tissue makes correctly locating difficult. A new regression method (Hara) utilizes leg length and has been shown to improve HJC location in cadavers and less error than previous pelvic based regression methods, such as those proposed by Harrington et al. This study compared the accuracy of the HJC location calculated with both of the Harrington methods and the Hara method. The coronal knee angle was calculated for each method using a static motion analysis trial, and compared to the tibiofemoral angle measured on a gold standard digital full-leg coronal radiograph. This study demonstrated that the Hara method was more accurate than either of the Harrington methods. The mean error between the gold standard x-ray measurement and the motion analysis calculation for the Harrington (stepwise and LOOCV), the Harrington (linear regression), and Hara regression methods, respectively were 6.0°, 4.0°, and 1.8°. Accurately modeling the HJC is critical for data interpretation and patient care. This study confirmed that the Hara HJC regression method is valid in an in-vivo setting.

1. Introduction

In biomechanical modeling for motion analysis, the hip joint center (HJC) is used to define the proximal location of the thigh segment. This is the point that defines the orientation of the thigh segment, which determines hip and knee kinematics. It is also the point about which the hip moments are calculated. The HJC cannot be palpated. For modeling purposes, its location must be calculated. Functional methods for HJC prediction have been shown to be accurate [1], but are difficult to perform for clinical populations with neuromuscular deficits. Therefore, regression based methods are preferred. However, these methods have been shown to yield large degrees of error. Most prediction methods utilize the pelvic landmarks (i.e. the anterior and posterior superior iliac spines) to calculate the location of the HJC [2–4]; yet excessive adipose tissue can make these landmarks difficult to locate and track correctly. A new regression equation utilizing leg length has been shown to improve the accuracy of locating the HJC in cadavers [5]. The Hara regression method has been shown to have considerably less error than the Bell [2] or Davis [3] methods and comparable error to the Harrington method [4]. In a previous review, the Harrington method was the most accurate predictive method to date and was the regression method recommended by the International Society of Biomechanics [6]. The purpose of this study was to compare the accuracy of the HJC location calculated with both of the Harrington HJC methods and the Hara HJC method. These three methods were compared to a gold standard digital full-leg coronal radiograph.

2. Methods

A diverse study population was used for this analysis (10/16 female; 45.6 ± 28.4 years; BMI = 25.0 ± 7.3). The cohort included 8 clinical patients with neuromuscular pathology visiting the lab for standard gait analysis and 8 patients with osteoarthritis undergoing total knee arthroplasty (TKA) who gave informed consent and were enrolled in a larger post-operative follow-up study. For the clinical patients both knees were included, while only the pre-operative surgical knee was included for the TKA patients in the comparison. All 16 subjects included in this study stood upright with their knees fully extended and their feet pointing forward for both the radiographic imaging and the static motion capture.

Tibiofemoral angles, calculated using standard digital full-leg coronal radiographs were used as the 'gold standard' for comparison. An angle measurement tool (QREADS: Clinical Image Viewer, Mayo Clinic, Rochester, MN) was used to create vectors from the center of the

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agreement between the HJC method and the gold standard was assessed with a linear regression analysis. The relative error between the each of the Harrington methods and the Hara method was determined with a paired *t*-test. The absolute error of each method was evaluated with a one-sample two-sided *t*-test.

2.1. RESULTS and DISCUSSION

This study demonstrated that the Hara regression method was a more accurate estimate of the HJC than either of the Harrington methods in the coronal plane (Fig. 1). The mean error between the gold standard x-ray measurement and the motion analysis calculation for the Harrington1 HJC regression method was 6.0° (confidence band: −1.52 to 13.53), for the Harrington2 HJC regression method was 4.0° (confidence band: −3.38 to 11.35), and for the Hara HJC regression method was 1.8° (confidence band: −3.9 to 7.43). The linear regression analysis showed a significant slope for both the Harrington1 (*p*-value = 0.000) and Harrington2 (*p*-value = 0.000) methods but not for the Hara method (*p*-value = 0.293). The Hara method was closest to zero, had the lowest variability, and did not have systematic error. The mean errors between the Harrington1 and Hara methods (*p*-value = 0.000) and the Harrington2 and Hara methods (*p*-value = 0.000) were statistically different; however, the mean error for the Hara method was still not zero (*p*-value = 0.007) in the coronal plane.

In the findings reported by Hara [5], the Harrington HJC regression model and the Hara HJC regression model had similar error. However, the Harrington method utilizes the pelvic depth distance in the model. This measurement has been shown to have larger errors in a clinical setting compared to medical imaging [9], which may be contributing to the superior performance of the Hara method to the Harrington method in this in-vivo population.

A limitation of this study was that the knee varus and valgus angles were not directly measured. While the x-ray measurements were considered a gold standard, there was still an approximation for locating the hip, knee and ankle joint centers to formulate the vectors used to represent the knee angles. Additionally, since only the coronal knee angles were analyzed in this study, only the medio-lateral position of the HJC is verified with these findings. The Hara method was based upon cadaver estimates. The patients included in this study included children and young adults with neuromuscular pathology and adults with osteoarthritis. This study confirmed that the method was valid in an in-vivo setting.

3. Conclusions

Accurately modeling the HJC is critical for data interpretation and patient care. This study confirms that the Hara HJC regression method is valid in an in-vivo setting.

Conflict of interest statement

There are no commercial relationships which may lead to a conflict of interest with any of the authors.

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