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Technical note

Accuracy of the functional method of hip joint center location: effects of limited motion and varied implementation

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Abstract

Accurate location of the hip joint center is essential for computation of hip kinematics and kinetics as well as for determination of the moment arms of muscles crossing the hip. The functional method of hip joint center location involves fitting a pelvis-fixed sphere to the path traced by a thigh-fixed point while a subject performs hip motions; the center of this sphere is the hip joint center. The aim of the present study was to evaluate the potential accuracy of the functional method and the dependence of its accuracy on variations in its implementation and the amount of available hip motion. The motions of a mechanical linkage were studied to isolate the factors of interest, removing errors due to skin movement and the palpation of bony landmarks that are always present in human studies. It was found that reducing the range of hip motion from 30° to 15° did significantly increase hip joint center location errors, but that restricting motion to a single plane did not. The magnitudes of these errors, however, even in the least accurate cases, were smaller than those previously reported for either the functional method or other methods based on pelvis measurements of living subjects and cadaver specimens. Neither increasing the number of motion data observations nor analyzing the motion of a single thigh marker (rather than the centroid of multiple markers) was found to significantly increase error. The results of this study (1) imply that the limited range of motion that is often evident in subjects with hip pathology does not preclude accurate determination of the hip joint center when the functional method is used; and (2) provide guidelines for the use of the functional method in human subjects. © 2001 Elsevier Science Ltd. All rights reserved.

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1. Introduction

Accurate location of joint centers is a necessary but sometimes difficult step in performing kinematic and kinetic analyses of movement. Location of the center of the hip joint is especially difficult because it is farther from palpable bony landmarks than are the centers of more distal joints. However, accurate hip joint center (HJC) location is critical to the calculation of muscular hip moments (Holden and Stanhope, 2000; Kirkwood et al., 1999; Stagni et al., 2000) and to the estimation of the moment arms of muscles crossing the hip (Delp and Maloney, 1993). Location of the HJC has been accomplished by radiographic methods (Bell et al., 1990; Fieser et al., 2000; Kirkwood et al., 1999) and by predictive approaches in which the hip center is located relative to palpated anatomical landmarks (Andriacchi et al., 1980; Davis et al., 1991; Kirkwood et al., 1999; Seidel et al., 1995; Tylkowski et al., 1982; Vaughan et al., 1992). The functional method of HJC location involves determination of the center of rotation between the femur and pelvis by fitting a sphere to paths followed by a femur-fixed point as motion occurs about the hip (Cappozzo, 1984; Leardini et al., 1999; Shea et al., 1997).

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by a single thigh-fixed marker (A-MKR) significantly affected HJC location accuracy.

The results of the present study do little to resolve the discrepancy between HJC errors for the functional method found by Bell et al. (1990) and Leardini et al. (1999). Leardini et al. (1999) attributed the larger errors found by Bell et al. (1990) to differences in "experimental and analytical methodology", but the present study showed that variation in the type of motion performed (the subjects of Leardini et al. (1999) performed an extra cycle of circumduction) and the use of a single marker rather than a centroid of multiple makers (Bell et al., 1990) have only minimal effects on HJC accuracy. Neither Bell et al. (1990) nor Leardini et al. (1999) provided details of their respective sphere-fitting procedures, however, and it may be the case that the method employed by Leardini et al. (1999) was better suited to finding sphere fit solutions that represented the global minimum of the objective function. In the present study this was accomplished by fitting a sphere repeatedly with initial guesses for the HJC coordinates randomly chosen from a large cube that contained the true HJC. Alternative strategies for choosing a starting point for the optimization that could be employed in vivo include making a single initial estimate of the HJC location based on either (1) the sphere that would be uniquely determined by four points selected from the experimentally-measured thigh motion trajectory; or (2) one of the predictive methods of HJC location.

In summary, the results of the present study suggest that the accuracy of the functional method of HJC location is not compromised when hip motion is limited, as has been suggested previously (Bell et al., 1990; Kirkwood et al., 1999; Seidel et al., 1995). The HJC location errors that resulted when linkage hip motions were limited to 15° were found to be significantly larger than in corresponding trials in which 30° of motion was possible, but these errors were small (<1 cm) compared to errors reported in previous studies of predictive or functional methods. Future human studies should explore whether the motions of normal walking are adequate for prediction of the HJC, thus obviating the need for special motion trials.

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