Clinical Implications of Using Spherical Fitting to Find Hip Joint Centers

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Introduction There is widespread agreement that determining hip center locations using conventional table-based methods is impractical for patients with certain physical characteristics. Some authors feel that table methods based on ASIS breadth measures are inaccurate in all populations (Seidel, et al. 1995). The functional method (spherical fitting) of estimating hip joint centers is being hailed by some as a better approach to consider for clinical use. However, research evaluating the accuracy of the functional method in contrast with more established methods of determining hip joint estimates is conflicting (Leardini et al., 1999; Bell et al., 1990). In addition, research targeted at evaluating the functional method in terms of motion requirements has been performed in non-clinical environments (Piazza et al., 2000).

Statement of Clinical Significance Given the importance of accurately identifying hip center locations (Stagni et al., 2000), the possibility of utilizing a more accurate approach is enticing. However, the clinical implications of using the functional method have not been fully explored. For example, the amount of hip motion required by the patient has not been established, especially in the context of noise generated by the measurement system and by soft tissue motion. Likewise, the impact of different marker sets and methods of marker attachment is not yet understood. The primary aims of this study are: 1) to determine the minimum hip motion characteristics necessary to achieve satisfactory results when implementing the functional method in clinic, and 2) to determine whether existing marker placement methods facilitate the estimation of hip joint centers using a spherical fit algorithm.

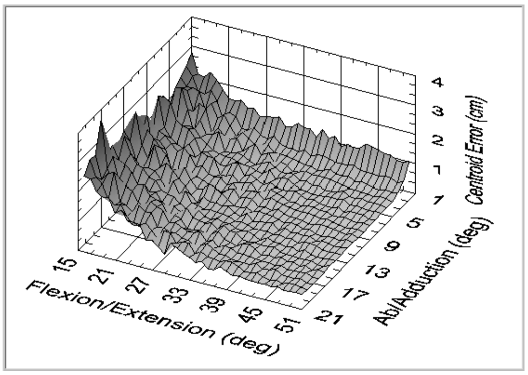
Methodology Our method of fitting a sphere to a given set of points was a least-squares algorithm, using the Gauss-Newton method to minimize the function:

$$f = r - \sqrt{(x_i - x_0)^2 + (y_i - y_0)^2 + (z_i - z_0)^2}, \textit{ where } (x_0, y_0, z_0) \textit{ is the derived centroid}$$

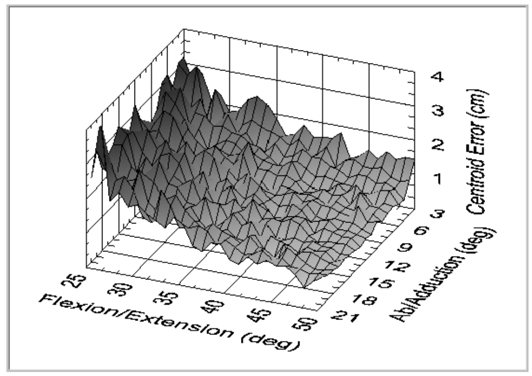
First, this algorithm was applied to simulated knee joint center positions generated by a software program that controlled the range of motion in two orthogonal planes and the amount of random radial noise introduced to the coordinates. The interactions between range of motion and noise were examined by systematically altering these parameters. The sphere-fitting algorithm was then applied to data collected from a subject wearing both a Helen Hayes (HH) and Cleveland Clinic (CC) marker set. For each marker set, the subject performed three walking trials as well as a standing trial with 60º flex/extension ROM and 40º abd/adduction ROM for each leg. The coordinate paths of the knee joint center relative to the pelvic frame of reference were used to estimate the hip joint center for each trial. The estimates from the gait trials, stationary leg movement trials, and constants based on inter-ASIS difference were compared for each marker set.

Results Utilizing a radius of 30 cm and radial noise of 0.5 cm, the analysis of the joint center estimate as a function of ROM indicated that more than 34º flex/extension ROM and 3º abd/adduction ROM were needed to estimate joint centers with less than 1 cm error. Increasing the abd/adduction ROM beyond 3º did not improve the results. As the radial noise increased to 1.0 cm, the estimated joint center error climbed to approximately 1 cm. This error increased slightly when the radial noise was increased to 1.5 cm. (See figures below.) Preliminary analysis of the clinical trial data showed that the functional method of estimating hip joint centers was within 3.0 cm of the table values for both the CC and HH marker sets for the standing hip movement trials. The HH marker set produced similar results for the walking trial, while the CC set estimated the hip centers an average of 7.3 cm from the table values.

Radial Error: 0.5 cm



Radial Error: 1.5 cm



Discussion The results from the simulation imply that requiring the patient to actively or passively move the hip through large ranges of flex/ extension and abd/adduction patterns during static trials may not be necessary. The ability to determine hip centers from walking data appears to be more dependent on the amount of noise than on the ranges of motion, provided that the patient exhibits at least 35º flex/extension and 3º abd/adduction. At the very least, those patients who do require standing trials can move the hip through a relatively small range of motion. While the standing and walking trials from the HH marker set and the standing trial from CC marker set produced results within a 3.0 cm range of the table values, the estimates from the CC walking trials biased the hip centers laterally by approximately 6.5 cm. This suggests that the CC set, which uses clusters on the thigh without a lateral knee marker during walking, produces systematic errors in the reconstruction of the knee joint centers. The addition of a lateral knee marker to the CC marker set during walking should reduce this error and improve the hip joint estimates from gait data. Further research is needed: 1) to characterize marker movement during gait and its effect on hip center estimates, and 2) to compare the clinical accuracy of the functional method to a radiographic standard.

References

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