EVALUATION OF IN VIVO HIP JOINT CENTER ESTIMATION BY THREE METHODS

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INTRODUCTION

Accurate estimation of joint centers is a main requirement in movement analysis. Uncertainty in joints centers estimation directly affects the accuracy of kinematic and kinetic calculations[1]. Different methods are proposed in the litterature to calculate hip joint center. Bell [2] presents a predictive model based on regression equations established in vitro. On the contrary, functional methods uses joint movement acquisitions and are based on the assumption that hip is a ball-and-socket joint. The sphere fitting method [3], and more recently the SCORE method [4] were described to determine the center of the joint. In vivo, Leardini [3] evaluates the hip joint center estimation by 2 methods (predictive method and functional method by sphere fitting method) compared to the center obtained by radiographic technic. The aim of the present paper is to evaluate the error on the hip joint center estimation by 3 methods (predictive, sphere fitting and SCORE) using the EOS® low dose bi-planar X-ray system (Biospace Med-Paris-France).

METHODS

Ten young volunteers were considered after informed consent and ethical committee approval. The protocol began with a stereo-radiography, using the EOS® system followed by a static acquisition using the VICON® system (Oxford Metrics-UK). Due to EOS® acquisition requirements, subjects stood with one foot slightly anterior with respect to the other. During VICON® acquisition, feet were aligned. For each subject, 4 reflective markers were placed on the iliac spines of the pelvis and 4 reflective markers were mounted on a plate placed on the thigh. Markers were not removed during both acquisitions in order to allow the registration from the EOS® reference frame to the VICON® reference frame. The femoral head and the markers were located on both radiographies, and their 3D coordinates were computed in the EOS® reference frame. The center of the femoral head was registered from the EOS to the VICON reference system by using (1) the markers placed on the thigh, and (2) the markers placed on the pelvis. The hip joint center belongs both to the femur and the pelvis so both registered centers of femoral heads should be superimposed. Therefore, the distance between both registered centers of femoral head provides an estimation of the hip joint center registration's accuracy. From pelvic markers, the position of the hip joint center could be calculated in the pelvic reference frame from the predictive equations of Bell.

In a second time, 3 VICON® trials were realized in which the subjects were asked to perform 3 different hip movements (named circum, cross and stararc). From these trials, 3D coordinates of the hip joint center were computed using both sphere fitting and SCORE methods. The distance between each estimated hip joint center and the hip joint center registered from EOS® using pelvic markers were calculated. Mean and standard deviation of the errors for the 10 subjects were obtained.

RESULTS AND DISCUSSION

The first result of the study is the accuracy of the registration technique. The mean distance between hip centers registered from pelvis and thigh markers is 9 mm (std : 4 mm). This reflects the soft tissues' movement relatively to the bones between the static positions even if both static positions are very closed. Considering that soft tissues are thinner on the pelvis, the hip joint registered from pelvic marker was taken as a reference. Figure 1 shows the mean and standard deviation of the estimation errors for the different methods compared to this reference. Using Bell equations, the estimation error is close to the value of Leardini [3]. On the contrary, the sphere fitting method leads to a greater inaccuracy in comparison with this previous study. The error is also more variable among subjects. The results show that the accuracy of hip joint center estimation is better using SCORE method than sphere fitting method. The stararc motion seems to bring the most accurate estimation of hip joint center.

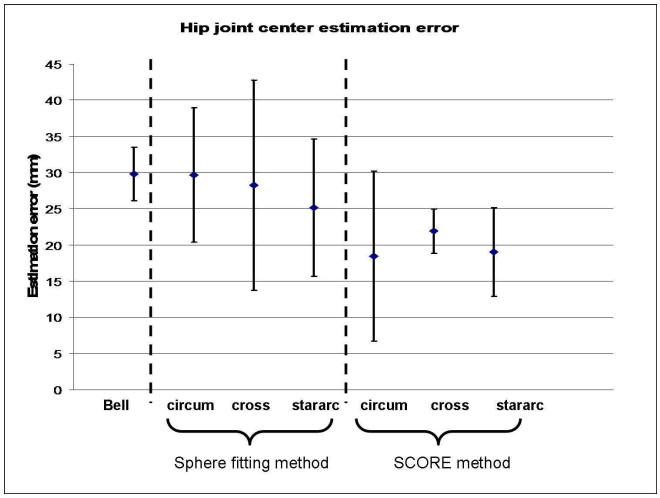

Figure 1: Error in the estimation of hip joint center from 3 different methods

CONCLUSIONS

Two main results are brought by this study. (1) the soft tissue artifact can be close to 1 cm between two static positions. (2) the SCORE method leads to the best estimate of hip joint center on a population of 10 subjects, compared to sphere fitting method and predictive method.

REFERENCES

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