Estimation of the wrist joint center of rotation

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1. Introduction

The human hand is involved in many daily human activities. The hand is connected to the forearm by the wrist joint which contributes to its special orientation facilitating the manipulation of objects (Hansen et al. 2017). However, the wrist joint has a complex organisation of carpal bones. Consequently, when describing wrist joint kinematics, an accurate kinematic model is necessary. The traditional approach for modelling the wrist joint is to consider it as a revolute joint (Vignais et al. 2014), hence requiring the localisation of the center of rotation of this joint. The aim of this paper is to compare three functional and one predictive method to estimate the center of rotation (CoR) of the wrist joint.

2. Methods

Nine healthy subjects (age: 31.67 ± 9.07 years, bodyweight: 72.33 ± 13.65 kg, height: 175.33 ± 11.06 cm) participated in the experiment. Subjects were asked to do three repetitions of flexion-extension (F-E) and abduction-adduction (A-A) movements of the wrist joint.

Eight 3-mm diameter markers were fixed on the skin above the metacarpal segment of the hand. Two 5-mm diameter markers were fixed on the ulnar and radial styloid processes, and one 5-mm diameter marker was fixed on the posterior face of the forearm. Data were collected using a motion capture system (17 cameras T160, Vicon, Oxford Metrics Ltd, Oxford, UK). Data analysis was performed using MATLAB 7.6 (Mathworks, Inc.; Natick, MA). Three repetitions in F-E and A-A were performed by the subjects during the motion capture.

Three functional methods and one predictive method were used to estimate the joint CoR. In the Plane-Fitting (PF) method, marker trajectories of the distal segment are assumed to be planar and circular. Least square planes and least square circles are calculated from the markers trajectories. In the Sphere-Fitting (SP) method, movements of markers in the distal segment are assumed to belong to spherical surfaces. A least square sphere is calculated from these trajectories (Devos et al. 2014). The symmetrical CoR estimation (SCoRE) is another functional method (Ehrig et al. 2006) to estimate the CoR. A predictive method was also used in this study to estimate the CoR as the mean point between the markers fixed on the ulnar and the radial styloid processes (Schmidt et al 1999).

3. Results and discussion

The mean distances between the CoRs computed from the functional methods and the CoR calculated from the predictive method (figure 2) ranged from 11 mm (SphereFit vs Predictive) to 25 mm (PlaneFit vs Predictive) in F-E. In A-A, these results ranged from 14 mm (SCoRE vs Predictive) to 61 mm (PlaneFit vs Predictive) in A-A.

These results suggest that CoRs computed with the SCoRE method are closer to the CoR computed with the predictive method. However, the Plane-Fitting method seems to be inappropriate for estimating the CoR of the wrist joint in the case of the A-A movement.

The Root Mean Square (RMS) computed in the case of F-E movement ranged from 0.03 mm (RMS plane fitting) to 0.8 mm (RMS circle fitting). In the case of A-A movement, the RMS ranged from 0.02 mm (RMS plane fitting) to 4.5 mm (RMS circle fitting).

As suggested in Gamage and Lasenby (Gamage and Lasenby, 2002), we used several markers per segment in order to provide redundant information for the estimation of the joint’s CoR. However, skin movement artefacts (Cappozzo et al, 1996) are responsible for marker movement relative to the underlying bone during motion. They may influence the estimation of the CoR between the different functional methods.
movements, the A-A movement cannot be considered as a circular movement. Further studies would be necessary to identify the different components of the A-A movement.

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