

COMPARISON OF THE GLENOHUMERAL ROTATION CENTER ESTIMATED BY FUNCTIONAL METHODS TO THE ANATOMICAL GLENOHUMERAL JOINT CENTER

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INTRODUCTION

The International Society of Biomechanics recommends the use of the glenohumeral rotation center (GH) to define the humerus coordinate system [1]. The GH can be estimated by predictive [2] or functional methods [3]. The predictive approach, which is based on regression equations of the scapula geometry, is mainly affected by errors on landmarks calibration, variability of bone morphology and the regression uncertainty. The functional methods infer the center of rotation from the relative motion of adjacent body segments [4-6].

Contrary to the GH, a number of studies about the hip joint center have compared different predictive and functional methods, the movement characteristics (type of movements, range of motion, velocity), the method type (to assume or not a rigid body motion) and the calculation time. To our knowledge, few studies have compared the different functional methods to locate the GH. However, the result of these methods is the location of the GH in the scapula coordinate system. And, at the moment, there is no comparison with the anatomical center of the humeral head obtained by medical imaging.

The aim of this study is to propose a comparison of estimated GH computed by functional methods with the glenohumeral anatomical center provided by magnetic resonance imaging (MRI).

METHODS

Four subjects took part in experiments. The motion analysis Vicon (Vicon®, Oxford Metrics Ltd, Oxford, UK) was used to record the kinematical data. Upper arm movements (3 flexions-extensions, 3 abductions-adductions and 3 circumductions) were performed continuously. Four markers were fixed on the upper arm as far as possible from the deltoid. Three markers were fixed on the scapula (Angulus Acromialis, Trigonum Spinae, Angulus Inferior). In addition, the scapula was covered with 120 markers. These markers were used to define more accurately the registration between the motion analysis and medical imaging.

Subjects lay in a prone position on an examination table in order to be in the same position as in the MRI. Immediately after the motion capture, subjects moved to the MRI to perform an imaging of the scapula and the upper arm. A robust iterative closest point algorithm was used to match the MRI and Vicon markers and visualize the bones in the motion coordinate system.

GH location was determined from the four markers on the humerus defined with respect to the coordinate system of the scapula with the methods of [5-9].

Sphere fitting method was used to approximate the humeral head. The glenohumeral anatomical center (GHAC) was then deduced from the center of the sphere.

RESULTS AND DISCUSSION

Comparisons between the methods showed a significant difference for the x-axis (upward/downward rotation) and z-axis (anterior/posterior tilt). For the x-axis, there was a significant difference between [7] and [6] ($p=0.014$) and between [7] and [9] ($p=0.015$). For the z-axis, there was a significant difference between [6] and [8] ($p=0.003$), [6] and [7] ($p=0.005$), [9] and [8] ($p=0.003$), [9] and [7] ($p=0.005$). [6] and [9] methods gave the same GH location as [8] and [7] methods.

The smallest distance between the GH and the anatomical center was obtained with the algorithm of [5] (11.38 mm). For the four others methods, the distance is superior to 15.25 mm. The highest distance was obtained with [6] (17.45 mm) (Figure 1). These distances were then normalized by the radius of the sphere. The method of [5] found the GH at half the radius of the sphere.

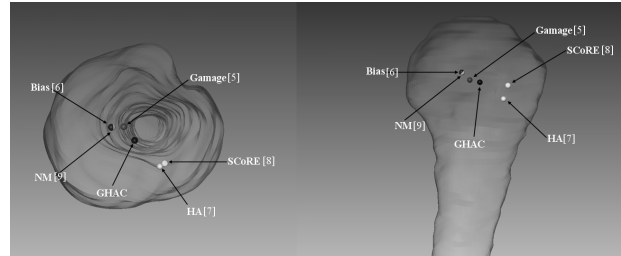


Figure 1: GH according to the 5 functional methods and anatomical centre of the humeral head (GHAC) computed by sphere fitting.

CONCLUSION

The location of the GH differs significantly according to the methods. The algorithm of [5] is the method which estimates the GH most accurately.

REFERENCES

1. Wu G, et al., *J. Biomech.* **38**: 981-992, 2005.
2. Meskers CGM, et al., *J. Biomech.* **31**: 93-96, 1997.
3. Leardini A, et al., *J. Biomech.* **32**: 99-103, 1999.
4. Halvorsen K, et al., *J. Biomech.* **32**: 1221-1227, 1999.
5. Gamage SSHU, Lasenby J, *J. Biomech.* **35**: 87-93, 2002.
6. Halvorsen K, *J. Biomech.* **36**: 999-1008, 2003.
7. Woltring HJ, et al., *J. Biomech.* **18**: 379-389, 1985.
8. Ehrig RM, et al., *J. Biomech.* **39**: 2798-2809, 2006.
9. Chang LY, Pollard NS, *J. Biomech.* **40**: 1392-1400, 2007.