Humeral Axial Rotation Measurement Through a Proximal Ulna Marker Cluster

Lorenzo De Sanctis[1,2], Umile Giuseppe Longo[1,2], Arianna Carnevale[1], Minah Waraich[3], Lawrence Gulotta[4], **Andreas Kontaxis**[3]
[1]Fondazione Policlinico Universitario Campus Bio-Medico, Via Álvaro del Portillo, 200, 00128 Rome, Italy
[2]Research Unit of Orthopaedic and Trauma Surgery, Department of Medicine and Surgery, Università Campus Bio-Medico di Roma, Via Álvaro del Portillo, 21, 00128 Rome, Italy
[3]Leon Root Motion Analysis Laboratory, Rehabilitation Department, Hospital for Special Surgery, New York, NY, USA
[4]Department of Sports Medicine and Shoulder Surgery, Hospital for Special Surgery, New York, NY, USA
Email: KontaxisA@hss.edu

Summary

Accurate measurement of internal/external rotation joint angle is critical in assessing the shoulder function, especially in clinical practice as it plays a key role in evaluating activities of daily living and monitoring the rehabilitation progress. This study analyzed the effectiveness of using a marker cluster placed over the proximal ulna to measure humeral axial rotation with respect to the thorax, comparing it with the traditional method that uses a cluster placed on the upper arm. Proximal ulna tracking showed a statistically higher maximum range of motion (ROM) than humeral tracking.

Introduction

Measurement of internal/external (or axial) rotation of the humerus is critical for the assessment of glenohumeral joint (GH) hypermobility, rotator cuff pathology, and rehabilitation [1]. An assessment performed by Cutti et al. showed that the error significantly affects the estimation of axial rotation, if a tracking cluster is placed directly on the upper arm [2]. This study introduced a novel marker set for shoulder kinematics, utilizing a proximal ulna cluster to measure humeral axial rotation.

Methods

Eight volunteers (male/female: 8/0, mean age: 34 ± 15 years, no shoulder pathologies) participated in the study. Markers were placed on the thorax landmarks (IJ, PX, C7, T8), and humerus epicondyles (ME, LE) of the dominant limb. Then, each volunteer was asked to prone/supinate the forearm at least 5 times from the pose shown in Figure 1a and a cluster was placed at the proximal epiphysis of the ulna, over the olecranon, where skin motion was minimal. Clusters were positioned on the acromion (AMC), upper arm, and thorax (Fig. 1) [3]. A functional shoulder circumduction task was performed by all the volunteers to determine the GH center. The bone-embedded frames (BEF) were defined as recommended by the ISB [4]. Two methods were compared for tracking the ISB "H1" BEF: one used the upper arm cluster (H), and the other used the GH center (from the scapular cluster) and the axis of elbow flexion-extension (PU). This axis was defined with a functional flexion/extension task and tracked by the cluster on the proximal ulna. Each volunteer was asked to perform 5 complete cycles of: (i) int/ext rotation from the Ski-Pose (Fig. 1b), (ii) int/ext rotation in the frontal plane with 90° elevation, (iii) int/ext rotation in the sagittal plane with 90° elevation. The active ROM was evaluated by averaging the five repetitions. Linear regression and a one-way ANOVA were performed.

Results and Discussion

Regression parameters and ROM values are reported in Table 1. In all eight subjects, R^2 was always above 0.9919. The linear coefficient a_1 was 0.64 ± 0.10 from the Ski-Pose, showing a 28 ± 6° difference in maximum range of motion between the proposed and conventional tracking methods. In the frontal plane with 90° elevation, a_1 was 0.73 ± 0.04, while in the sagittal plane at 90° elevation, it was 0.74 ± 0.05. A one-way ANOVA confirmed significant differences between proximal ulna and conventional methods for all tasks, with $F(1,14)$ ranging from 21.398 to 107.4, $p < 0.001$, and η^2 between 0.605 and 0.885. The results suggest proximal ulna tracking yields greater ROM measurements of humeral axial rotation compared to the upper arm cluster technique in the analyzed tasks.

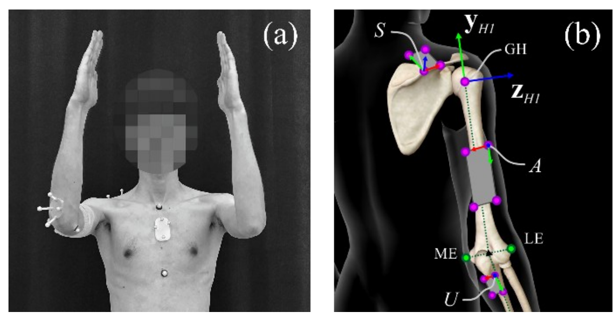

Figure 1: (a) Volunteer with proximal ulna cluster placed on the right limb (frontal view). (b) Scapular, humeral, and proximal ulna clusters and frames.

Conclusions

The analyses showed that measuring shoulder internal/external rotation using a marker cluster on the proximal ulna offers a more realistic alternative to humeral clusters due to soft tissue artifact. Bone pins and biplane fluoroscopy will be used to validate the proposed marker set.

References

[1] Escamilla et al. (2009) *Sports Medicine* **39** 663-685
[2] Cutti et al. (2005) *Gait Posture* **21** 341-349
[3] Warner et al. (2015) *J. Vis. Exp.*, **96**: e51717
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Table 1: Coefficient of determination, linear regression coefficient, and ROM for both the proximal ulna and the humeral tracking are reported.

INT/EXT TASK	R^2	a_1	ROM – PU [°]	ROM-H [°]
Ski-Pose	0.9956	0.64 ± 0.10	83 ± 8	55 ± 12
Frontal Plane	0.9977	0.74 ± 0.05	131 ± 13	98 ± 13
Sagittal Plane	0.9978	0.73 ± 0.04	121 ± 8	88 ± 5