

Location of the best confident scapula cluster during a forward humeral elevation

¹ Fabien Leboeuf, ^{2,3} Sylvain Brochard, ^{2,3} Mathieu Lempereur, ⁴ Cedric Schwartz and ^{2,3} Olivier Remy-Néris
¹CHU Nantes, Hôpital saint Jacques, pole Médecine Physique et Réadaptation, 85 rue saint Jacques, 44093 Nantes
¹CHU Brest, hôpital Morvan, service Médecine Physique et Réadaptation, 5 avenue Foch, 29609 Brest
³Laboratoire d'Analyse et de Traitement de l'Information Médicale, INSERM, UMR_S 650, IFR 148, Brest
⁴Laboratory of Human Motion Analysis, University of Liège, Belgium
fabien.leboeuf@gmail.com

SUMMARY

Eleven subjects were equipped with a cluster of 120 markers on the scapula. Forward humeral elevation was then performed. Robust estimators are used in order to eliminate high deformation. Results underline the modification of the best cluster during elevation. Markers located on the lateral posterior part of the acromion were identified. They could be the best ones to measure dynamic scapula rotation during entire elevation.

INTRODUCTION

Non-invasive kinematic analysis of the scapula encumbers experimental difficulties. Skin deformations are associated with sliding movement which affect external skin markers.

Shape tracking method [1,2] or optical-mechanical measurement system [3] are only ones able to consider both sliding and deformations. However, calculation time and specific experimental acquisition process are the main limit factors for enlarging to clinical applications. Moreover, Biomechanics provides kinematic optimizations [4] well-adapted for a bone surrounding by skin (eg femur). Skin markers are supposed to be rigid with bone. In the case of scapula, rigid markers can change. Most of researchers have paid attention to acromion due to thin skin. Devices are usually placed on it for kinematic studies. This location appears as a consensus but Bourne et al. [5] analyzed markers on the lateral part of the scapula. In consequence, his study could lead to reconsider the rigidity of acromion, especially in dynamic conditions.

Optimization method with external markers would be improved if it can track the rigid location. Our study aims at using an robust registration method for a cluster of 120 markers on the scapula. The rigidity obtained by robust estimators for the three points recommended by ISB, Acromion Cluster (AC) and Lateral Scapula Cluster (LSC) are compared. The entire cluster could also inform on the best confident cluster to use for a dynamic study of a forward humeral elevation.

METHODS

Eleven healthy subjects were equipped with a scapula cluster composed of more than 120 markers (Figure 1a). AC, LSC are made up of 9 markers and 19 markers

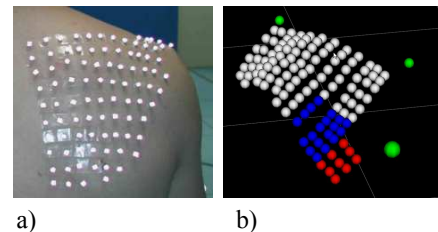


Figure 1: (a) cluster shape. (b) Acromion Cluster (red) – Lateral Scapula Cluster (blue)

During the experiment, subjects lay in a prone position on an examination table. Five forward humeral elevations were performed along a wooden board on which lines indicate the degree of elevation. Cluster coordinates were recorded with seven cameras (VICON Mx13) at a frequency of 120 Hz.

Let us consider \mathbf{q}_i and \mathbf{p}_i , all embedded vectors of the reference cluster and the mobile cluster respectively. A robust registration method consists in minimizing :

$$\min \left[\sum_i w_i \mathbf{e}_i^2 \right] \text{ where } \mathbf{e}_i \text{ are the residue and } w_i \text{ are weighted factors.}$$

The robustness stems from the ability to reject high residue due to deformation. To this end, the Biweight Tukey estimators [6] is applied. w_i is then a decreasing function of e_i and a scale factor. This latter is usually defined by the median absolute deviation. In consequence, this method is adaptative. w_i are updated at each time. They reflect the confidence of each embedded vectors and thus markers. A value closed to 1, informs of maximal rigidity with the reference cluster.

A repeated measurement ANOVA with two factors (selected clusters, humeral angles), and an alpha level at 0.05 was performed to detect significant differences between Tukey estimators associated with AC, LSC and ISB markers. When appropriate, a post-hoc Tukey test was carried out.

RESULTS AND DISCUSSION

Figure 1 presents an example of Tukey estimators color map. It lets appear the displacement of the best confidence cluster from the acromion to the cranio-caudal part of the scapula along the elevation

The statistical analysis confirms this comment (figure 1). From 0 to 40°, AC presents the highest estimators. Significant differences with ISB markers and LSC are observed. The point Trigulum Spinae (TS) slides under the skin. Matsui et al. [7] showed a displacement of 86.8mm from its initial position. A marker placed on TS cannot track this anatomical point.

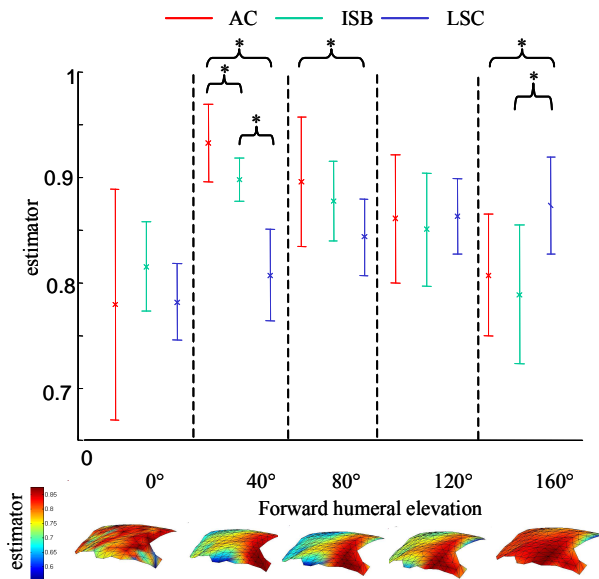


Figure 2: (Up) Value of Tukey estimators for each selected clusters, * p-value > 0.05. (Down) Color map example of Tukey estimators calculated for one subject .

An alternative methodology based on AC would be preferred. From 80 to 120° of humeral elevation, the discrepancy between selected clusters decreases. The deltoid displacement starts to affect the anterior part the acromion. At 120°, no significant differences were observed, but when the deformation reaches its maximum at 160°, LSC appears to be the best confident cluster. This displacement complies with recommendations for analyzing scapula movement. Indeed, Andel [8] reported that abnormalities cannot be detected above 100° of elevation with a tripod cluster on the flat part of acromion.

In addition, Figure 2 presents for all subjects the location of the four markers presenting the highest values of the estimators along the entire extension. These markers are concentrated on the lateral posterior part of the acromion. In this fact, this observation tends to validate the use of devices (tripod or electrogoniometer) placed on the acromion.

In the case of cluster analysis directly placed on skin, the association of weighted factors with optimization method might improve reliability of kinematic parameters.

CONCLUSION

This study applies a registration method associated with robust estimators. These latter inform of rigid location in comparison with a reference cluster. Results appear as in accordance with observations of skin deformation during a forward humeral elevation. Best confident clusters for the entire elevation is located on the lateral posterior part of the acromion. Further studies should compare estimated rotations with bone displacements obtained with either an invasive method or a palpation approach. A well selected cluster might improve the accuracy of the scapula rotations.

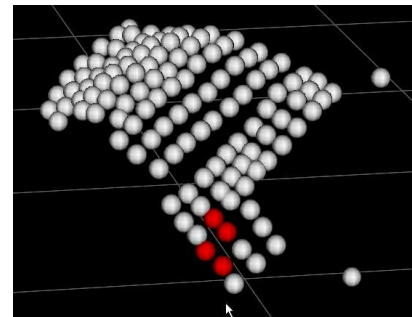


Figure 3: Location of the four markers with the highest value of Tukey estimators during entire forward elevation

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