MULTIBODY KINEMATIC OPTIMIZATION OF SCAPULAR KINEMATICS: THE EFFECT OF MARKER WEIGHTS

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Introduction

Scapular motion is essential for shoulder movement comprehension. To estimate scapular kinematics, skin marker-based method is generally used, but its accuracy suffers from soft tissue artefacts (STA)[1]. Experimental methods have been developed to improve scapular kinematic estimates, placing markers on the acromion or the scapula spine, but none of them fully annihilate scapular misorientation. Numerical methods have also been developed to further improve kinematics, such as multibody kinematic optimization (MKO), including point-on-ellipsoid scapulothoracic joint. Furthermore, weights applied to individual markers can be adjusted in MKO to counteract for STA local distribution. But the influence of individual marker weight on scapular kinematic accuracy has never been investigated. This study aimed to assess the influence of weights applied to the scapula markers on scapula kinematic estimates.

Methods

Fifteen healthy volunteers were equipped with 24 reflective-skin-markers and mimicked fourteen analytical, daily living and sport movements. The latter were equally decomposed in five static poses, to allow for the positioning of a scapula locator. Two kinematic models were implemented and scale using OpenSim. The reference model (REFmodel) was composed of the thorax and scapula segments with six degrees of freedom each, and anatomical landmarks from the scapula locator were used for inverse kinematics. The second model (MKOmodel) was adapted from Seth et al. [2] with a subject-specific point-on-ellipsoid scapulothoracic joint. Segment kinematics were estimated with MKO from skin markers. Especially for the scapula, six markers on the acromion and scapular spine were used. Weights of the scapula were optimized for each participant and each movement by minimizing the average scapular misorientation (θ) on the five poses (t) of each movement:

$$\theta = \frac{1}{T}\sum_{t=1}^{T=5} cos^{-1}\left(\frac{trace\left(R_{MKO}{}^{-1}(t)\ \cdot R_{REF}(t)\ \right) - 1}{2}\right)$$

with R_{MKO} and R_{REF} the rotation matrices from scapula to thorax obtained from both the models. All optimized weighting sets were averaged and the three weighting procedures (homogenous vs optimized vs average) were compared using a linear mixed model.

Results

Mean weights from all optimized weighting sets for scapula markers ranged from 0.05±0.14 to 0.32±0.32 (Figure 1).

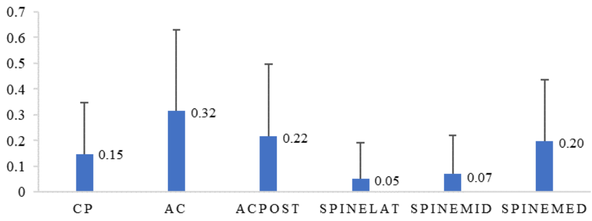

Figure 1: Mean (± standard deviation) optimized scapular relative weights (sum = 1) of all participants and all movements.

When weighting sets were individually optimized, significant smallest scapular misorientation was found ($p<0.001$; θ=14.6±3.7°), with a reduction of scapular misorientation ranging from -0.9±0.5° to -12.1±36.3°. By contrast no significant differences were observed between homogenous and mean optimized weighting set ($p=0.547$; θ=18.3±7.8° and θ=19.2±11.3°, respectively).

Discussion

Marker weight optimization resulted in improvements similar to those previously described with MKO methods [3]. Variability in the optimized weights highlighted the importance of marker redundancy for scapular kinematic estimates in MKO. In addition, weighting sets showed subject- and movement-specificity, which could be explained by subject- and movement-specific STA [1]. Nevertheless, for daily-based kinematic analyses, weights optimization appeared unsuitable.

This study presents some limitations. Using a scapula locator can be considered a "silver standard method" and optimization results were dependent on the kinematic model used.

To conclude, when estimating scapular kinematics in upper limb MKO, the use of homogenous weights applied on redundant markers located from acromion to scapular medial border spine are recommended.

References

1. Blache et al, J Biomech, 62:39-46, 2017.
2. Seth et al, PLoS One, 11(1): e0141028, 2016.
3. Michaud et al, International Biomech, 4:86-94, 2017.