Comparing Glenohumeral Joint Kinematics Using Motion Capture and Two OpenSim Shoulder Models

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Introduction: The shoulder is a complex system with three joints that provide a large range of motion. One approach for studying this system is through musculoskeletal computer models. Several shoulder models exist. However, differences between models can make it challenging to select the "right" model for studying any given biomechanical problem. The aim of this study is to evaluate whether two shoulder models, which each include distinct shoulder joint definitions, provide equivalent interpretations of glenohumeral joint motion.

Material and Methods: One healthy subject (female, 19 years) participated in this IRB approved study. A 12-camera motion capture system (Vicon Vero; Oxford, United Kingdom) measured the position of 25 markers placed on the right arm and upper body [1, 2]. The subject completed four trials of three movements: shoulder abduction, shoulder flexion, and shoulder extension. Each movement started at a natural standing position with the palm facing medially and elbow extended. After three seconds, the arm was raised and lowered in the direction of each movement. To evaluate glenohumeral joint motion, two models were scaled by the subject's height and weight using static marker data and shoulder joint angles were calculated using inverse kinematics in OpenSim v 3.3 [3]. The first model was the MoBL-ARMS model, which defines the shoulder using 3 glenohumeral degrees-of-freedom and prescribed scapular motion [4]. The second model was the scapulothoracic model, which similarly defines the glenohumeral joint with 3 degrees-of-freedom, but also includes 4 degrees of freedom that enable unconstrained scapular motion [5]. For each model and movement, average ranges of motions were calculated and compared.

Results and Discussion: The joint angles output by the two models are not equivalent. For example, for both the abduction and extension tasks, all three glenohumeral degrees of freedom demonstrate a larger range of motion in the MoBL-ARMS model than in the scapulothoracic model (Fig. 1). This trend does not hold for the flexion task (Fig. 1). There are several possible explanations for the differences in range of motion magnitude between models. Differences in scapular motion between the two models would affect the reported ranges of motion because the glenohumeral joint defines the motion of the humerus relative to the scapula. Differences in how each model's joint definitions scale could also contribute to differences in model output. Even though the differences in magnitude can be explained, these differences can be problematic. For example, our results indicate that a researcher's interpretation of range of motion magnitude will be different based on which model is used. Similarly, a researcher's interpretation of trial variability is dependent upon the model implemented, as the standard deviations were higher for the MoBL-ARMS model than the scapulothoracic model (Fig. 1).

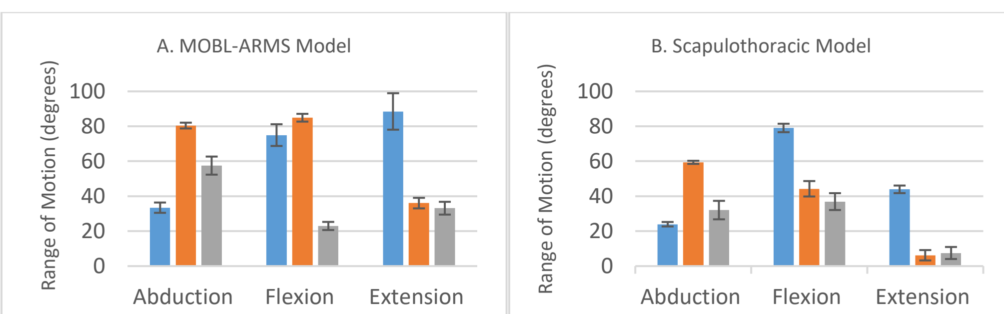

Figure 1. Mean (± st. dev.) range of motion for each task (abduction, flexion, and extension) calculated for elevation angle (blue), shoulder elevation (orange) and shoulder rotation (gray).

Conclusion: This study highlights the importance of carefully selecting shoulder models when studying upper limb movement because kinematic outputs, such as joint range of motion, can vary based on how the underlying joints are defined. In the near future, additional data will be collected to evaluate to what extent the reported results hold across multiple subjects and when examining more complex tasks. Additionally, we will examine motion of the humerus relative to the thorax (instead of the scapula) to control for differences in scapular motion.

References: [1] Naaim et al. *J Biomech.* 2017 62: 102-109. [2] Wu et al. *J Biomech.* 2005 38(5): 981-992. [3] Delp et al. *IEEE Trans Biomed Eng* 54(11): 1940-1950. [4] Saul et al. *Comp. Method Biomech Eng*. 2015 18(13):1445-1458. [5] Seth et al. *PLOS ONE.* 2016 11(1): e0141028.