VALIDATION OF A MUSCULOSKELTAL HUMAN SHOULDER MODEL DURING A FORWARD FLEXION MOTION

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Introduction

Being an un-constrained joint, the shoulder can present numerous pathologies [1]. Shoulder biomechanics can be studied using non-invasive modelling tools, such as *in-silico* and *in-vitro* studies. These tools help to better understand shoulder biomechanics and the potential impact of pathologies or surgical techniques on the shoulder biomechanics. Computational shoulder modelling and in particular musculoskeletal modelling has been previously developed. One key element of these models is their validation; however, not all of them are using experimental data. Therefore, the goal of this study was to develop and validate a musculoskeletal shoulder model. The validation was performed using data from an experimental study.

Methods

OpenSim, an open-source software [2], was used to develop a musculoskeletal shoulder model. The model (Figure 1) is a subject-specific six degree of freedom (DoF) model based on previously published models [3,4]. The model includes eight Millard 2012 Equilibrium type muscles with a total of fourteen fibers (Anterior Deltoid (AD), Lateral Deltoid (LD), Posterior Deltoid (PD) (three fibers each); Supraspinatus (SSP), Infraspinatus (ISP), Subscapularis Superior (SBS) and Inferior (SBI), Teres Minor (TM) (one fiber each)). The model uses the International Society of Biomechanics coordinate system [5]. Forward flexion kinematics from our in-house cadaveric shoulder simulator (eight muscle-actuated, six DoF) were input into the musculoskeletal model. The forward flexion movement consisted of glenohumeral elevation from 0 to 45°, -30° external rotation and 50° anterior to the scapular plane. Muscle and joint reaction forces of the musculoskeletal model were calculated using Concurrent Optimization of Muscles Activation and Kinematics (COMAK) algorithm [6]. The forces calculated by COMAK were compared to the forces generated by the cadaveric shoulder simulator actuators to validate the model. The Pearson correlation coefficient, r, was used to represent the relationship between muscles forces from the musculoskeletal model and those measured by the shoulder simulator and thereby assess the validity of the *in-silico* approach.

Results

Muscle forces from the musculoskeletal model and the cadaveric shoulder simulator showed strong correlation during the simulated forward flexion (Pearson's r>0.5, Figure 1) expect for SBI (Pearson's r = -0.19).

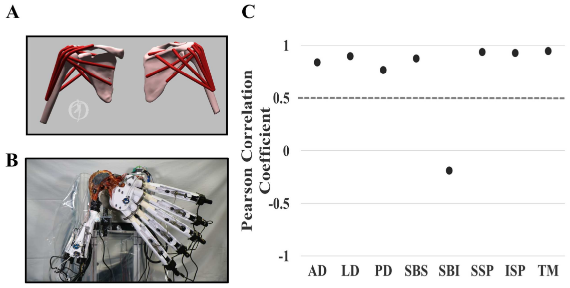

Figure 1: (A) Musculoskeletal model; (B) Pearson Correlation coefficients of muscle forces of the musculoskeletal model and the cadaveric shoulder simulator for the simulated forward flexion {Grey dashed line - Pearson's r = 0.5}; (C) Cadaveric shoulder simulator

Discussion

A good agreement was observed between the musculoskeletal model predictions and the muscle forces measured *in-vitro* for a forward flexion motion. The discrepancy between the model estimated and the experimental force for the SBI can be explained by the fact that the SBI is not a dominant muscle during forward flexion. The method described in this study will provide a non-invasive tool for assessing the impact of shoulder pathologies and surgical techniques on the shoulder biomechanics during different activities.

References

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