MUSCLE ATTACHMENT POINTS AND MAXIMAL ISOMETRIC FORCE IMPACT GENERIC MUSCULOSKELETAL MODEL PREDICTIONS

Natalia Belotti MSc[1], Hamed Hosseini PhD[1], William R. Taylor PhD[1], Fransiska M. Bossuyt PhD[1]

[1]Laboratory for Movement Biomechanics, ETH Zurich, Switzerland

Email: natalia.belotti@hest.ethz.ch

Summary

This study examines how uncertainties in subject-specific muscle and tendon parameters affect shoulder loading using probabilistic modelling. Data from 10 healthy subjects were used with a scaled musculoskeletal model to perform Monte Carlo simulations. Results showed significant variability in muscle activation and glenohumeral (GH) joint reaction forces (JRFs), with muscle attachment points and maximum (max) isometric force being the key factors. Personalizing these parameters can reduce error estimations of shoulder loading.

Introduction

Although subject-specific soft-tissue characteristics are thought to play a critical role in injury mechanics, their influence on shoulder loading, estimated using generic musculoskeletal modelling, remain unclear. In this study, a probabilistic modelling approach was used to quantify to what extend uncertainties in subject-specific muscle and tendon parameters, generally taken from small cadaveric datasets which do not necessarily reflect the study population, impact shoulder loading.

Methods

Shoulder kinematics and muscle activations were collected using motion capture and surface EMG in 10 healthy subjects (age (mean ± std) 23.8 ± 0.7 years, 4 males and 6 females)) from 12 upper-limb muscles (including thoracoscapular, glenohumeral, and rotator cuff muscles) during arm elevation and depression in several planes. A generic musculoskeletal shoulder model [1] was scaled to subject anthropometry and validated against surface EMG and in-vivo forces [2]. Monte Carlo (MC) simulations and sensitivity analyses were used to assess the impact of uncertainty by perturbing the max isometric muscle forces, muscle attachment points, optimal fibre lengths, and tendon slack lengths with static optimization (SO) repeated for each variation.

Results and Discussion

The probabilistic analyses underscored the significant impact of muscle attachment points and max isometric force on the accuracy of GH JRFs and muscle activation predictions. General MC simulations, which perturbed all parameters simultaneously, showed activation and GH JRF variability of 0.02-0.45 BW and 0.2-0.5 BW, respectively. Muscle attachment points contributed 80% (0.12-0.40 BW) and max isometric force 30-50% (0.06-0.25 BW) to this variability. Optimal fiber and tendon slack length induced 15-60% (0.05-0.25 BW) variability, increasing with abduction angle. The supraspinatus showed the highest errors (0.2 BW), likely due to their key role in maintaining controlled GH JRFs and consistent muscle activation, which are essential for joint stability by ensuring balanced load distribution and joint integrity [3]. Personalizing rotator cuff parameters could reduce GH JRF errors by 0.2–0.4 BW.

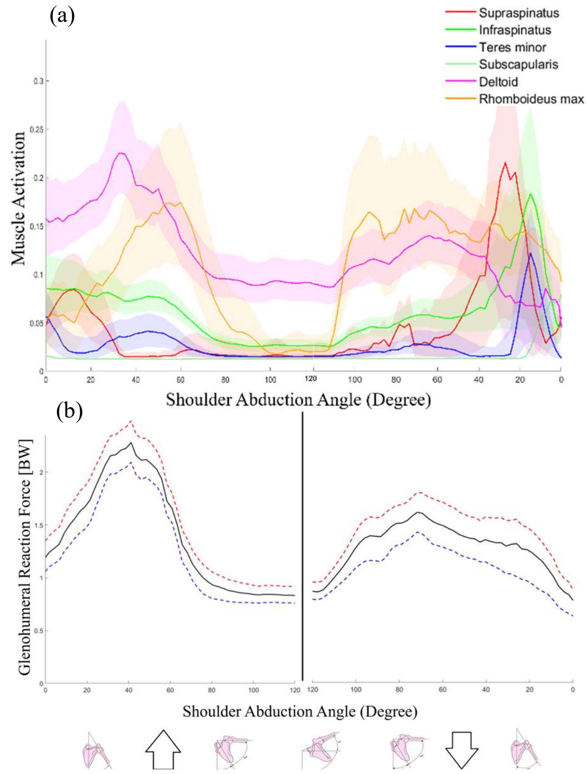

Figure 1: (a): *Muscle activations from a subset of muscles in the general Monte Carlo simulation with perturbed input parameters. Shaded areas represent the 5th to 95th percentiles. (b): GH JRFs [BW] vs. Shoulder Abd. Angle [°]: The black line represents the mean, with blue and red dotted lines indicating the 5th and 95th percentiles, showing error variation in non-personalized parameters.*

Conclusions

Overall, our findings demonstrate that accounting for muscle attachment points and max isometric forces reduces error variability in estimated muscle activation and GH JRFs. Integrating subject-specific variations in musculoskeletal parameters may improve estimates of shoulder loading.

References

[1] Seth A. et al. (2019). *Front Neurorobotics*, **13:90**.

[2] http://www.OrthoLoad.com

[3] McCLure PW. Et al. (2001) *JSES.*, **267-277.**