A Customized Musculoskeletal Model to Investigate Shoulder Loading Across Sitting Postures

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Summary

This study introduces a spine-integrated thoracoscapular shoulder (SITS) musculoskeletal model that couples a state-of-the-art thoracoscapular shoulder model with lumbar and cervical spinal articulation. Including spinal articulation results in more realistic estimates of shoulder movement. With the SITS model, we observed compensations and changes in shoulder loading profiles induced by sitting in a slouched vs. upright posture.

Introduction

The state-of-the-art thoracoscapular musculoskeletal shoulder model has accurately reproduced scapular kinematics [1] but neglects any spinal articulation, i.e. the spine is fused. Inverse kinematics tracks body motion with the modeled kinematic chain; ignoring spine kinematics will influence estimated shoulder joint angles, muscle moment arms, and glenohumeral joint contact force (GH-JCF). Our objectives were to first, compare computed shoulder biomechanics with the spine fused (locked) and articulated (unlocked, SITS model) during dumbbell lifting in a slouched sitting posture, and second, to investigate influences of upright vs. slouched sitting postures on shoulder biomechanics during dumbbell lifting.

Methods

Participants, 6 able-bodied participants (males, age 27.8 ± 1.0 y, mass 66.6 ± 8.9 kg, height 175.0 ± 4.2 cm) performed 3 raise tasks with a 2.5-kg dumbbell in 3 directions: posterior, anterior, and lateral in two sitting postures: slouched and upright. The SITS model was developed by adding kinematic models of the lumbar [2] and cervical [3] spine to the thoracoscapular shoulder model [1]. The SITS model was linearly scaled for each participant and the rapid muscle redundancy solver [4] was used to estimate muscle force and joint contact forces with locked and unlocked spine models.

Results and Discussion

Upon visual inspection, the SITS model with unlocked spine reproduced the trunk and spine positions more accurately than with the locked spine (Fig. 1). Model estimates kinematics, moment arms and muscles activation were sensitive to tracked spinal articulation. Estimated GH-JCF magnitude in the posterior raise task was lower (0.5 BW less, $p < 0.05$) and directed closer to the glenoid cavity center with unlocked vs. locked spine. This indicates that ignoring spinal articulation led to differences in muscles recruitment strategy. In other tasks, significant differences were present in joint angles, moment arms and muscles activation.

Using SITS model with unlocked spine, sitting posture was found to influence joint kinematics. For example, in lateral raise task, with the upright posture, participants could lift to the target height (head height) with glenohumeral shoulder elevation, whereas in the slouched position, the glenohumeral joint approached its mechanical limit at a lower dumbbell position, and participants instead extended their lumbar spine to lift to the target point. Muscles recruitment strategy was altered with posture due to changes in moment arms. With slouched posture, for instance, the medial deltoid was activated less, and the triceps was activated more. Similar alterations were observed in other tasks.

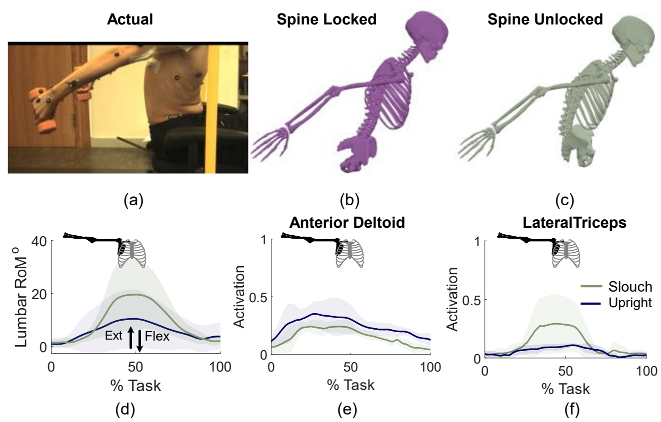

Figure 1: (a) Photo from experiment. (b)-(c) Reproduced movement in posterior lift with SITS model with locked and unlocked spine. (d) Lumbar spine flexion and (e)-(f) muscle activation during lateral lifting in different sitting postures.

Conclusions

Musculoskeletal simulation of the shoulder biomechanics is sensitive to modelling spine articulation. With the SITS model, we estimated the influences of sitting postures on shoulder movements and loading during raising tasks in different positions. Future application involves studying shoulder loading in users of manual wheelchairs, who tend to sit in a slouched position depending on core muscle strength.

References

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[2] Beaucage-Gauvreau, 2019. *CMBBE* **22**: 451–464.
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