Bilateral Compensation Occurs with a Unilateral Rotator Cuff Tear During Performance of Loaded Bimanual Tasks

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Summary

Bimanual tasks are difficult to complete with a rotator cuff tear (RT), but it is unknown if bilateral compensation occurs with a unilateral injury. A bilateral model was developed and to examine the effects of a unilateral RT on performance of loaded bimanual tasks. Results revealed that bilateral muscle compensation and kinematic deviation occurred during task performance for both a static posture and a dynamic task.

Introduction

Rotator cuff tears are one of the most prevalent causes of shoulder pain in the US, accounting for 33% of reported musculoskeletal pain [1,2]. Increased pain coupled with decreased function make daily activities difficult to perform [2]. Prior work shows that uninjured muscles compensate to enable task performance [3]. Many daily activities are bimanual, but the effects of unilateral RT on bilateral muscle compensation and task performance are unknown. The goal of this work was to develop and use a bilateral model of the upper extremity to examine the effects of a unilateral RT on muscle compensation during loaded static and dynamic tasks.

Methods

A bilateral musculoskeletal model was developed in OpenSim software (v3.3) [4] by reflecting existing rotational and translational definitions of the unilateral MoBL-ARMs model [5]. A shared load (13.3N or 44.5N) was added to the hands via a weld joint (left hand) and weld constraint (right hand) to replicate holding a box. The models were further developed to represent a unilateral RT of 4 varying severities, ranging from no tear to a massive tear. Low posture and high posture static tasks and a dynamic forward reach task were used as inputs to the Computed Muscle Control [6] algorithm. The point kinematics tool was used to track the position of the box during each task. Average force for each of the 13 muscles crossing each shoulder was normalized to model specific peak isometric force. Maximum deviation was used to quantify shared load position. Quantitative and qualitative trends were examined and compared across models of varied RT and task.

Results and Discussion

For all tasks, on the injured side, the deltoid and teres minor, increased force contribution to enable successful task performance (Fig. 1A). However, on the unaffected side, minimal muscle compensation occurred for the low and high posture static tasks (Fig. 1B). For the dynamic task, infraspinatus increased muscle force by 91% for the massive tear, 44.5N load on the unaffected side, indicating bilateral muscle compensation to enable task performance.

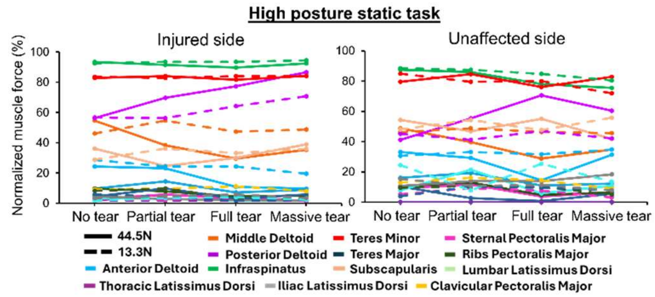

Figure 1: Average normalized muscle force for the high posture static task for the injured and unaffected sides.

Greatest box deviation occurred for the massive tear, 44.5N load for the high posture static and dynamic tasks. For the high posture static and dynamic tasks, the shared load deviated inferiorly (342mm; 7.2mm) and toward the unaffected side (83mm; 1.5mm), respectively (Fig. 2), suggesting that task kinematics are altered during with unilateral injury.

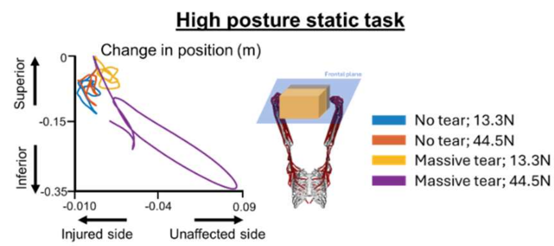

Figure 2: Change in position of the shared load across no tear and massive tear models for the high posture static task.

Conclusions

Results from this work identified bilateral compensatory muscles, such as the deltoid and teres minor. More work is needed to further investigate these trends and expand upon these findings to inform RT rehabilitation. The model developed here permits further investigation of the bilateral mechanisms driving functional deficits following injury.

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