Subscapularis Tendon Loading During Activities of Daily Living

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Disclosures:

Introduction: The subscapularis tendon is the largest of the four rotator cuff tendons and provides dynamic anterior stability as well as internal rotation of the shoulder. The subscapularis anatomy has been described as superior, middle, and inferior tendinous bands (fascicles). The superior band has a broad and more medial insertion site than the lower bands. Prior research has supported that the different aspects of the tendon provide differential functions with regard to dynamic anteroposterior stability as well as shoulder movements during activities of daily living. Surgeons commonly encounter partial tears of the subscapularis. There is little in the literature to guide the treatment of these tears, and there is no consensus on which tears require surgical fixation. The aim of this investigation was to gain a better understanding of the function of the three bands of the subscapularis and determine the threshold for repair. HYPOTHESIS: The superior band of the subscapularis tendon provides more anterior stability and is more active than the middle or inferior bands during Activities of Daily Living (ADL).

Methods: Shoulder Biomechanical Model
An established shoulder biomechanical model, the Newcastle Shoulder Model (NSM) [1] was used to predict the load of the subscapularis muscle during 10 common ADL. The primary outcome of the model was to measure the load in the subscapularis, the percentage of load in each of the three bands, and the muscle moment arms and contact forces in each of the three bands of the subscapularis. The model consists of six rigid bone segments that were digitized from the Visible Human (VH) dataset [2]: thorax, clavicle, scapula, humerus, radius and ulna. These are connected by three spherical joints (3DoF), the sternoclavicular (SC), acromioclavicular (AC), glenohumeral (GH) and two hinge joints (1DoF) at the elbow. The muscle morphology was taken from the literature [3,4]. Muscles are represented as elastic strings that wrap around simple geometric shapes (e.g spheres and cylinders) that describe the bony geometry. Large site muscles are represented with multiple lines of action (elastic strings) that follow anatomical fascicle division (bands). In the model there are in total 90 lines of action representing 31 muscles and 3 ligaments (sternoclavicular, conoid, coracoid). The subscapularis was modeled with 3 lines of action representing the superior, middle and inferior bands of the muscle. The lines were wrapping around the humeral head that was modeled as a sphere.

Kinematic Inputs and Model Prediction
In its final state, the model can predict muscle and GH joint contact forces for a given motion. Forces are calculated using inverse dynamics and optimization techniques [1,3]. A set of kinematic data was imported to the model to calculate muscle moment arms and forces as well as GH joint stability and contact forces [5]. The data set includes upper arm and scapula kinematics and describes common hygiene, feeding and every day object tasks (Table 1). The tasks were recorded with a motion analysis system (8 camera VICON, Oxford Metrics) and were performed by 10 healthy volunteers (average age 35 years old, average weight 70.5 kg, 4 female and 6 male).

Results: Muscle loading results showed multiple levels of activations for the subscapularis across the ADLs. The maximum load for the whole muscle ranged between 0.05 to 0.43 times body weight (BW) across all subjects (Fig. 1). The most demanding activities were tasks 9, 10 and 3. Analysis of the load sharing between the three subscapularis bands showed that the superior part carries most of the total load of the muscle (ranging from 81 - 100 %, Fig. 3). The contribution of the middle and inferior bands is limited with the exception of Task 3. The muscle load results are in contrast with the moment arm results which show that the inferior band had the largest internal rotational moment arm.

Discussion: The superior band of the subscapularis tendon is more active and takes the most percentage of load than other aspects of the tendon during common ADLs despite having the smaller rotational moment arm compared to the middle or inferior band. The later implies that the model activated the subscapularis bands in a way to provide glenohumeral joint stability instead of balancing internal rotational torques. Internal rotation strength was mainly provided by activating other internal rotators (e.g Pectoralis).

Significance: The results of this study suggest that most of the subscapularis load is transferred through the superior tendon band. Thus it is suggested a low threshold for repair of tears that involve the superior portion of the superior tendon in order to maximize functional outcomes post-operatively. However, clinical studies are needed to determine if the results from this biomechanical evaluation can be extrapolated to patients.
Acknowledgments:


<table>
<thead>
<tr>
<th>Activity</th>
<th>Area of Use</th>
<th>Activity</th>
<th>Area of Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Reach to opposite axilla</td>
<td>Hygiene</td>
<td>6. Drink From Mug</td>
<td>Feeding</td>
</tr>
<tr>
<td>2. Reach to opposite side of neck</td>
<td>Hygiene</td>
<td>7. Answer telephone</td>
<td>Everyday object</td>
</tr>
<tr>
<td>3. Reach to side and back of head</td>
<td>Hygiene</td>
<td>8. Brush left side of head</td>
<td>Hygiene</td>
</tr>
<tr>
<td>4. Eat with hand to mouth</td>
<td>Feeding</td>
<td>9. Lift block to shoulder height</td>
<td>Everyday object</td>
</tr>
<tr>
<td>5. Eat with spoon</td>
<td>Feeding</td>
<td>10. Lift block to head height</td>
<td>Everyday object</td>
</tr>
</tbody>
</table>

Figure 1: The total maximum force exerted by the subscapularis muscle (all three bands) varied across the activities.
Figure 2: Percentage of load-sharing between the 3 bands (fascicles) of the subscapularis.