EFFECT OF BICEPS TENDON RUPTURE ON MAXIMAL ISOMETRIC ELBOW FLEXION AND FOREARM SUPINATION TORQUE

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INTRODUCTION

It is well known that the biceps functions mainly as an elbow flexor and forearm supinator. In vivo elbow flexion and forearm supination strength testing after rupture of the long head of the biceps tendon has shown decreases of 0-16% and 0-21%, respectively [1,2]. Although many studies have attempted to identify the role of the long head of the biceps brachii muscle in elbow flexion and supination, the mechanical role of this biarticular muscle in these movements remains unclear. One reason it is difficult to pinpoint the roles of individual muscles is because there is no method to measure individual muscle forces *in vivo*. To overcome this problem, researchers [3-7] have developed computer models of the upper extremity to estimate individual muscle forces and joint-reaction forces at the shoulder, elbow, and wrist. The purpose of this study was to determine the individual muscle contributions to maximal isometric elbow flexion and forearm supination torque with and without a biceps tendon. Specifically, simulations representing an intact shoulder and simulations representing an isolated short head rupture, an isolated long head rupture and a combined (short+long head) biceps rupture were compared and contrasted.

METHODS

Muscle forces during maximum isometric elbow flexion and forearm supination exercises were calculated using a detailed musculoskeletal model of the upper extremity (UE) that has been described in detail previously [3-5]. The model includes all of the major articulations from the shoulder girdle proceeding distally to the wrist [Fig. 1]. Thirteen degrees of freedom are used to describe the orientations of seven bones: clavicle, scapula, humerus, radius, ulna, carpal bones, and hand. The joints of significance in this investigation, the sternoclavicular joint, the acromioclavicular joint, and the glenohumeral joint – are each modeled as a three degree-of-freedom ball-and-socket joint. The articulation between the scapula and thorax is based on the model reported by van der Helm (1994). Forty-two muscle bundles representing the actions of 26 muscle groups of the UE actuate the model [5]. The force generating property of each muscle-tendon actuator in the model is calculated from a Hill-type model of muscle force. Each muscle is divided into separate bundles according to the groupings of muscle fascicles [7]. Maximum isometric exercise was simulated by solving a static optimization problem in which muscle activations were calculated subject to maximum torque developed at the elbow for a given position of the arm. Maximum isometric elbow flexion and forearm supination were simulated with the elbow flexed to 90 degrees and the forearm supinated. Rupture of the short and long head of the biceps was simulated by detaching the tendon from its bony insertion on the scapula. In both cases, none of the surrounding tissues that are often associated with injury to these structures were compromised (i.e., intertubercular ligament, coracohumeral ligament, glenoid labrum).

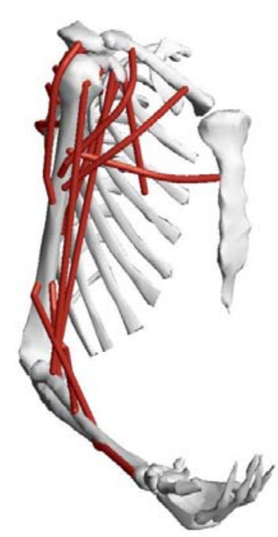

Figure 1: Elbow flexion and forearm supination exercise were simulated with the model shoulder in anatomic position and the elbow flexed 90 degrees.

RESULTS

The maximum torque produced for elbow flexion (78 Nm) and forearm supination (12.3 Nm) compares favorably with the maximum isometric torque measured from test subjects [5]. The total torque produced for elbow flexion was 78 Nm (Fig. 1). The model brachialis (Bra) produced 770 N of force and 22 Nm of elbow flexion torque that accounted for

28% of the total torque developed during maximal elbow flexion. The Biceps long head (BicL) produced more force and torque compared to the biceps short muscle (BicS) during elbow flexion. When the biceps long head was removed (NoBicL), the total torque decreased 22% to 61 Nm from the intact condition. When the biceps short head was removed (NoBicS), total torque decreased 18% from the intact condition. With both of the biceps heads ruptured (NoBiceps), the total flexion torque is decreased 40% from the intact condition. Pronater teres (PronT) developed 517 N and the brachioradialis (Brd) developed 99 N of force. However, both muscles yielded about the same amount of torque at the elbow, 7 Nm and 6 Nm, respectively. This is attributed to the smaller moment arm for the pronator teres when the elbow is flexed at 90°. The individual contributions of both of these muscles to the total torque output was less than 10%.

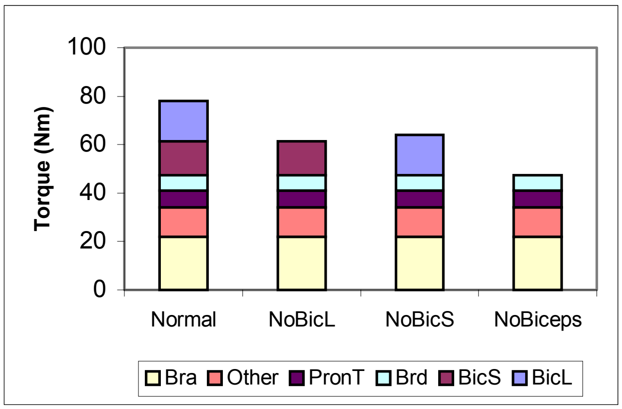

Figure 2: Maximum isometric elbow flexion torque for the normal and ruptured biceps.

During elbow supination, large muscle forces were developed in the model biceps short head (BicS), biceps long head (BicL), brachialis (Bra), brachioradialis (Brd) and supinator (Supi) muscles, despite the relatively small net torque (12.3 Nm) exerted at the joint (Fig. 2). Both biceps muscles along with supinator muscle developed more than 150 N of force. Brachialis and brachioradialis developed 40 N and 90 N, respectively. However, very small torques were exerted by these muscles in supination. Biceps brachii muscles generated large supination torque at the elbow joint which accounted for 78 % of the net torque. Both biceps heads yielded almost the same torque during supination. An isolated rupture of the biceps long head produced a 40% decrease in supination torque, whereas an isolated rupture of the biceps long head produced a 38% decrease. A combined long head and short head rupture reduced the supination torque by 78% (from 12.3 Nm to 2.6 Nm). Without the two biceps , net supination torque is dominated by the supinator muscle in the model.

DISCUSSION

These results suggest that rupture of the biceps will reduce elbow flexor torque up to 40% and forearm supination torque up to 78%. These values are larger than those found in in vivo studies. The model may have overestimated the decreases in torque because pain inhibition and the ability for other muscles to compensate for the rupture of the biceps are not accounted for in the simulations. Furthermore, surrounding tissues that are often associated with biceps tendon pathology were not compromised in the model. Thus, these values most likely represent the upper limit of torque deficits that could be expected in such injuries.

CONCLUSIONS

Complex shoulder injuries such as the injury or loss of the biceps tendons can be simulated utilizing complex computational models, and these techniques allow clinicians to isolate and more clearly understand potential functional deficits. However, one must also take into account limitations such as pain inhibition, adaptive muscular compensations and patient variability when applying these results clinically. Within the scope and limitations of this study, loss or injury to the biceps long and short heads may create functional deficits in maximal elbow flexion and supination torque output. It remains to be determined if these deficits would affect submaximal activities of daily life.

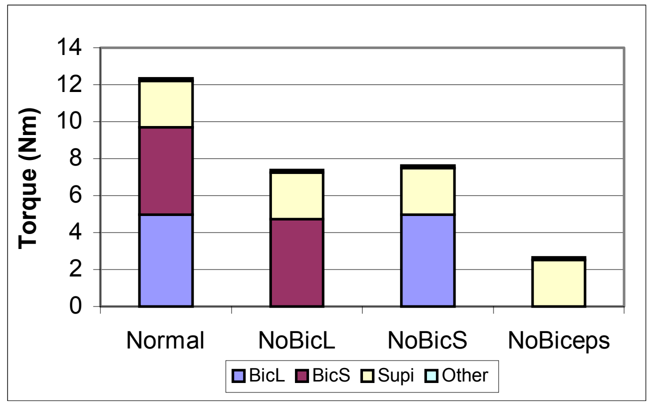

Figure 3: Maximum isometric forearm supination torque for the normal and ruptured biceps.

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