MUSCLE OPERATING RANGE INCLUDES OPTIMAL LENGTH AT EXTENDED JOINT POSTURES FOLLOWING BRACHIORADIALIS TENDON TRANSFER

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INTRODUCTION

Intraoperative sarcomere length measurements have provided evidence that transferred muscles are often attached longer than optimal length during tendon transfer surgery [1]. These data suggest that outcomes of tendon transfers may be sub-optimal because muscles are too long to generate adequate active force. However, minimal data are available that describe active muscle function following tendon transfer. As a result, the influence of surgical tensioning on clinical outcomes has not been established in patients.

Brachioradialis, an elbow flexor, is commonly transferred to the paralyzed FPL, a thumb flexor, following cervical spinal cord injury. This procedure is intended to restore active lateral pinch and to improve the ability to use the hand. Because brachioradialis (Br) changes length with elbow flexion, we expect pinch force to vary with elbow position following this transfer. The aims of this study are: (i) to quantify changes in pinch force with elbow flexion following Br-FPL transfer and (ii) to estimate the operating range of the transferred muscle on the isometric force-length curve.

METHODS

Lateral pinch force produced during maximum effort was quantified in 7 subjects (8 limbs) with Br-FPL tendon transfers. Pinch force was measured with the shoulder positioned at 90° flexion and in both an extended (0°-25° flexion) and a flexed (80°-126° flexion) elbow posture. The elbow was externally stabilized; wrist position was not constrained but was recorded during testing. Passive force was also quantified as a function of elbow and wrist position. The component of lateral pinch force due to active muscle contraction was calculated by subtracting the passive force at the appropriate posture from the measured pinch force.

Using a computer model of the upper extremity [2] we estimated the length of the Br-FPL transfer as a function of elbow and wrist position. The muscle-tendon path of Br was altered in the model to simulate transfer to FPL. PCSA, optimal fiber length, and pennation angle for the transfer were defined to be the same as for Br. Tendon slack length was adjusted to simulate 30 different surgical attachment lengths. For each subject, we calculated the attachment length that best matched the observed change in active pinch force given the measured elbow and wrist positions. The simulations assume full activation and that the observed differences in active pinch force result from isometric force-length properties.

RESULTS AND DISCUSSION

Median lateral pinch force produced by the subjects was 25.2 N with the elbow extended (range = 7.9 N-45.9 N) and 17.5 N with the elbow flexed (5.0 N–36.1 N). Subjects extended their wrists while pinching; median wrist position was 51° extension with the elbow extended and 57° extension with the elbow flexed. In the wrist postures adopted during maximum effort, median passive force was 1.2 N (0.6 N-2.7 N) with the elbow extended and 1.0 N (0.5-1.5 N) with the elbow flexed.

Differences in active pinch force ranged from a 15% increase to a 39% decrease with elbow flexion. Based on these data, the computer simulations indicate that the transferred brachioradialis operates at lengths that include optimal length when the wrist is extended (Fig. 1). We estimate that median resting sarcomere length (zero activation, 10° elbow flexion, wrist in neutral) is 2.83 µm among these subjects (circles and labels in Fig. 1 indicate range). This length is approximately 20% shorter than the average resting sarcomere length measured in the transferred Br during surgery (different patients). With a resting sarcomere length of 2.83 µm and with the wrist extended between 50° and 60°, optimal length (i.e., peak force) occurs between 34° and 44° elbow flexion.

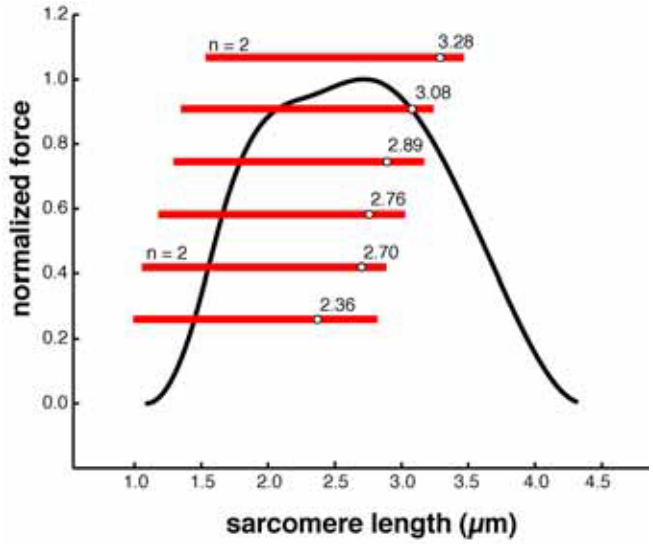

Figure 1. Br-FPL operating ranges as a function of elbow flexion (8 subjects). Wrist position is 55° extension, forearm is neutral, thumb is positioned for lateral pinch. Red bars indicate sarcomere length ranges during full muscle activation from 0° to 130° elbow flexion. Circles indicate resting length at 10° elbow flexion, neutral wrist and forearm, and the same thumb posture.

CONCLUSIONS

The data are consistent with length ranges that maximize force with both the elbow and wrist extended. This work suggests that the surgical attachment length chosen (which was not quantified in these subjects) did not result in post-operative lengths that were too long for active force generation.

REFERENCES

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