USE OF THE LONG FLEXOR AND INTRINSIC THUMB MUSCLES TO RESTORE LATERAL PINCH IN THE TETRAPLEGIC THUMB: A CADAVER STUDY

[1]Joseph D. Towles, [2]Vincent R. Hentz, and [3]Wendy M. Murray
[1]Sensory Motor Performance Program, Rehabilitation Institute of Chicago; [2]Dept. of Surgery, Stanford University;
[3]Bone and Joint Center, VA Palo Health Care System; email: towles@northwestern.edu

INTRODUCTION

In tendon transfer surgeries designed to restore lateral pinch following tetraplegia, the donor muscle is commonly attached to the insertion of the paralyzed flexor pollicis brevis muscle (FPL), a thumb flexor [1]. However, the nominal direction of the thumb-tip force that FPL produces may cause the thumb to slip during lateral pinch [2]. The aim of this study was to evaluate if actuating additional thumb muscles via tendon transfer could orient the thumb-tip force more appropriately for lateral pinch.

METHODS

Thumb-tip forces produced by the extrinsic and intrinsic muscles of the thumb were measured in 11 upper extremity cadaveric specimens by adapting an experimental approach previously developed for the index finger [3]. Briefly, a force of 10 N was applied to the tendons of nine muscles and the resulting three-dimensional (3D) thumb-tip force was quantified using a force sensor. The wrist was positioned in neutral and the thumb was fixed so that the trapezio-metacarpal joint was extended 29°, the metacarpo-phalangeal joint was flexed 27°, and the interphalangeal (IP) joint was flexed 50° to simulate lateral pinch.

For each muscle, median components of the measured thumb-tip force vectors were computed. Using this data, we calculated the resultant thumb-tip force vector from linear combinations of (1) the forces produced by FPL and one other muscle, and (2) the forces produced by FPL and two other muscles. Direct comparisons of the directions of the force vectors resulting from the linear combinations of multiple muscles were compared to the nominal FPL direction to evaluate if actuating more than one muscle could better orient thumb-tip force. We used the Mardia-Watson-Wheeler Test for circular statistics (Kovach Computing Services, Anglesey, Whales, UK) to test for significance ($\alpha = 0.05$).

RESULTS AND DISCUSSION

When the tendon of FPL was loaded with 10 N of force, the median (interquartile range) magnitude of the force was 1.7 N (1.5 N to 3.9 N) and the force was oriented obliquely at 49° (19° to 54°) with respect to the palmar direction in the flexion-extension plane (Fig. 1). We estimate that if equal force is applied to the tendons of the ulnar head of the flexor pollicis brevis muscle (FPBu) and FPL, i.e., if these muscles were simultaneously actuated by a single donor muscle, the resultant thumb-tip force direction is 15° (-20° to 27°). A single donor muscle actuating three muscles, FPL, FPBu and the radial head of the flexor pollicis brevis, also re-orients the force; the new orientation being -9° (-49° to 2°) with respect to the palmar direction.

Surgical restoration of lateral pinch following cervical spinal cord injury often leaves a donor-muscle-actuated FPL as the only muscle producing force at the thumb. Based on the coefficients of friction between skin and objects of different materials [4], we estimate that the force applied to an object by the thumb should be oriented to within 15° to 33° of the palmar direction to stably grasp objects. The direction of FPL's nominal force lies outside this range. This mis-direction likely explains the need for procedures that stabilize the IP joint, frequently performed concomitantly with tendon transfers that restore lateral pinch [5]. This study suggests that simultaneously actuating additional muscles with the same donor muscle has the potential to improve thumb-tip force direction. This approach could reduce the need for joint stabilization procedures that restrict joint movement, such as percutaneous pin fixation.

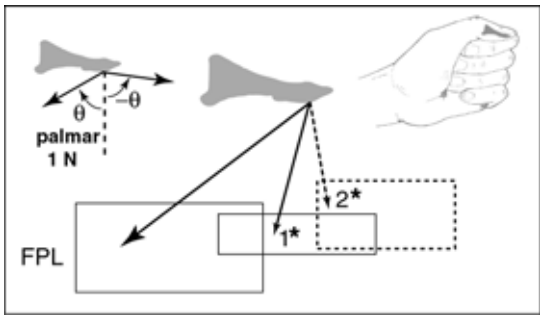

Figure 1: Median thumb-tip force directions. FPL and FPBu combined (1) and FPL, FPBu, and FPBr combined (2) yield force directions that are less oblique (more palmarly directed) than FPL alone. Boxes indicate the interquartile ranges of the thumb-tip force components. (*$p < 0.05$)

Limitations of this work should be considered when interpreting the results. First, thumb-tip force directions should also be evaluated in three-dimensions to evaluate how actuating multiple muscles would influence function in other planes. Second, we assume forces produced by multiple muscles can be combined linearly. The sensitivity of our results to this assumption should be further evaluated [6].

CONCLUSIONS

Actuating the paralyzed intrinsic musculature of the thumb via tendon transfer has the potential to improve lateral pinch function following tetraplegia.

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