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ORIGINAL RESEARCH

Evaluation of a Task-Based Intervention After Tendon Transfer to Restore Lateral Pinch

M. Elise Johanson, DPT,[a] Christine A. Dairaghi, BS,[a] Vincent R. Hentz, MD[a,b]

From the [a]Veterans Affairs Palo Alto Health Care System, Palo Alto, CA; and [b]Department of Surgery, Stanford University, Palo Alto, CA.

Abstract

Objective: To quantify changes in pinch force and brachioradialis (BR) activation after a task-based training program designed to improve pinch force after BR to flexor pollicis longus (FPL) transfer.

Design: One-group repeated-measures design compared pinch force and BR activation pre- and posttraining. Significant differences were tested with Wilcoxon signed-rank tests for pairwise comparisons at the $P \leq .05$ level.

Setting: Testing occurred in a Veterans Affairs Medical Center research laboratory and training was in a home setting.

Participants: Participants with cervical spinal cord injury (SCI) and previous BR to FPL transfer were enrolled in the study (N = 8). Six patients completed the training program and posttraining measures.

Interventions: The 10-week training was a home program that included novel activities to increase BR activation and practice producing pinch force in a variety of upper limb postures. Participants were provided with the task-based training equipment and instructed to practice 3 times per week.

Main Outcome Measures: Fine-wire electromyography of the transferred BR was recorded in maximum effort pinch force (N). Secondary measures included the strength and activation of the antagonist elbow extensor.

Results: Pinch force increased 3.7N (.38kg) and BR muscle activation increased 10% ($P \leq .05$) after the training. There was no increase in elbow extension strength, but participants with previous posterior deltoid to triceps transfer achieved greater activation of the antagonist elbow extensor.

Conclusions: The findings from this pilot study suggest that outcomes of tendon transfer and conventional therapy can be improved for patients with chronic cervical SCI.

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Individuals with cervical spinal cord injuries (SCIs) resulting in tetraplegia experience severe loss of hand function because of weakness and paralysis of the muscles below the elbow. For individuals with C5-7 level SCI, surgical transfer of the distal tendon of a strong brachioradialis (BR) muscle to the tendon of the paralyzed flexor pollicis longus (FPL) muscle has been widely reported to restore pinch strength.[1-8] In a systematic review of BR to FPL outcomes, Hamou et al[8] reported the surgery restored on average 19.6N (2kg) of pinch force, with outcomes ranging from 9.8 to 39.2N (1−4kg). Although many individuals report a high degree of satisfaction with the outcome of surgery, the magnitude of restored pinch force is variable.[6-8]

Muscle reeducation after BR to FPL transfer involves learning to activate the BR as a thumb flexor to perform tasks that require lateral pinch strength. Prior to surgery, low levels of force (3N) may be produced by actively extending the wrist to create passive tension in the extrinsic finger and thumb flexor tendons, referred to as tenodesis pinch.[9] After surgery, the relocation of the distal BR tendon to the FPL enables an active pinch. The restored pinch strength depends on the ability to voluntarily activate the transferred BR to flex the thumb. Postoperative activation of the transferred BR in maximum effort pinch has been reported to be only 35% of that recorded in elbow flexion for individuals with tetraplegia and long-term (1−23y) BR to FPL transfers.[3] Because individuals are capable of greater activation of the transferred BR in elbow flexion compared with thumb flexion postoperatively, there is potential for learning to increase the activation of the BR in pinch with a directed therapy program.

There are multiple factors that contribute to the functional outcome of BR to FPL surgery. Because the transferred BR continues to produce an elbow flexor moment because of its proximal attachment on the humerus, a strong contraction of the BR in pinch must be balanced by a strong contraction of the elbow

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extensor.[3,10] A number of studies have also shown that postoperative pinch strength is reduced in the absence of a strong elbow extensor.[3,4,10] In addition, individuals must learn to activate the BR in a variety of upper limb postures to perform functional tasks. Pinch force, recorded from individuals with (n=7) and without (n=2) tendon transfers to the thumb, was reduced in upper limb postures that simulated functional tasks requiring pinch strength (using an automated teller machine [ATM] machine, zippers, remote, plug, and fork) compared with self-selected postures.[11] These findings suggest the BR is not fully reeducated to produce pinch force in functional postures.

Conventional postoperative therapy provides instruction for protecting the transfer until healing is complete, activates the transferred BR in its new role (pinch), and directs individuals to practice functional tasks that require pinch strength.[12] Depending on individual resources, patients may be discharged to their local community without directed training in how to practice using the transferred muscle. Consequently, muscle reeducation (ie, learning to activate the transferred BR in pinch tasks) will be determined by attempting daily activities and not by a focused rehabilitation program under the supervision of a therapist. The availability and prescription for directed therapy after discharge could be a contributing factor for achieving successful surgical outcomes.

The purpose of this pilot study was to assess changes in pinch function after an experimental task-based home exercise program. Measures of pinch force and muscle activation of the transferred BR and the antagonist elbow extensor were recorded before and after the training program to characterize the underlying impairments that may be affected by the training program. Individuals with longstanding surgeries were included to determine if the training program would produce improvements beyond what was achieved by conventional therapy and performing daily activities after discharge. The goal of the training program was to prescribe specific activities that would increase BR activation in pinch tasks. A key element of the training program was to produce active pinch in a variety of upper limb postures to improve coordination with the antagonist elbow extensor. It was expected that greater pinch force magnitude after the training would be associated with higher BR activation and the ability to stabilize the elbow. A home-based setting was selected because travel to a clinic to receive directed therapy after discharge was impractical for most patients.

Methods

Participants

Participants with chronic cervical SCI and previous BR to FPL transfer were recruited. The International Classification for Surgery of the Hand in Tetraplegia was used to determine if an individual would benefit from BR to FPL surgery.[1,2] All participants were previously evaluated by the same surgeon (V.R.H.) and were in International Classification for Surgery of the Hand in Tetraplegia group ≥2 (manual muscle test grade 4 BR and grade 4 or 5 wrist extension strength). If BR to FPL transfer recipients had weak or absent (manual muscle test <3) elbow extension strength, a tendon transfer to restore elbow extension strength was also performed.

Patients were identified in hand and upper extremity clinics during routine follow-up visits and invited to participate in the pilot study. Individuals were included if they had a clinical diagnosis of cervical SCI, were at least 1 year postinjury, and were at least 1 year post−BR to FPL surgery. These time periods were chosen to ensure participants were neurologically stable and that they would have completed a conventional postoperative therapy program after their tendon transfer surgery. We anticipated the postoperative pinch force levels of the participants would be representative of the normative variability after BR to FPL surgery, but no effort was made to choose individuals with specific pinch force outcomes.

Volunteers were excluded if they lacked adequate independence or assistance from a caregiver to set up the exercise equipment properly or if they had >1 transfer to restore lateral pinch, but not if they had concomitant transfer procedure to restore elbow, wrist, or grasp function. Other exclusion criteria included significant spasticity in the upper extremity or pain that would limit ability to perform the exercises.

List of abbreviations:

ATM	**automated teller machine**
BR	**brachioradialis**
EMG	**electromyogram**
FPL	**flexor pollicis longus**
MVC	**maximum voluntary contraction**
PD	**posterior deltoid**
SCI	**spinal cord injury**

Study design

This study used a 1-group repeated-measures design with 1 pre- and 1 posttraining session in a research laboratory setting. The primary outcome measures included pinch force and muscle activation from the transferred BR. Secondary measures included elbow extension strength and muscle activation recorded from the antagonist elbow extensor. The task-based training was a 10-week home exercise program. After the pretraining measurement session, participants were given instructions for performing each activity in the training program and for setting up the exercise equipment in the home environment. A posttraining session was scheduled for repeat measurements after the training was completed. Informed consent, approved by the local institutional review board, was obtained prior to testing.

Pre- and posttraining assessment procedures

The participants were seated in their own wheelchairs for the testing. The EMG and force data were collected using LabVIEW data acquisition software[a] to convert analog signals from the electrodes and force sensors to digital information. The EMG and pinch force data were recorded simultaneously as participants produced their maximum effort pinch. Figure 1 shows the experimental setup for recording the force data. The participant was instructed to hold the force sensor without producing force (rest), produce their maximum effort pinch force for 5 seconds, and return to holding the force sensor without pinch force effort. Real-time visual feedback was provided for the time sequence and force sensor signal.

Pinch force

Maximum effort pinch strength was recorded in 2 conditions: with and without support of the upper limb (see fig 1A and B). The supported condition was used to test the participants' ability to produce pinch force without additional task demands (eg, controlling elbow and forearm position). In the supported condition,