Muscular Force Transmission Following Tendon Transfer

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BACKGROUND: Tendon transfers to antagonistic sites are orthopedic surgical procedures that are intended to improve gait or upper extremity function in individuals with severe disabilities. However, the result after recovery can be surprisingly variable. To improve our understanding of the adaptive processes occurring following a tendon transfer and to identify mechanisms determining the final result, a systematic study is necessary. As there are several limitations of studying tendon transfers in humans (e.g., it is not possible to perform a second surgery for experimental measurements), we used an animal model to test the hypothesis that tendon transfer surgical procedures result in connective tissue adaptation that alter force transmission from the transferred muscle.

METHODS: Under aseptic conditions, using isoflurane anesthesia, a flexor carpi ulnaris (FCU) tendon transposition was performed to the extensor carpi radialis (ECR) tendon within the right forelimb of male Wistar rats (n = 3, body mass ~200 g at the time of surgery). To monitor tendon-to-tendon attachment, small metal markers were implanted for later visualization in X-ray images. One month postoperatively, force transmission from FCU was evaluated. In anesthetized rats, joint movement upon excitation of FCU, using indwelling electrodes, was assessed (n = 2). Subsequently, the distal tendon of the ECR-FCU complex as well as the distal tendon of palmaris longus muscle (PL) were transected and connected to force transducers. Connective tissues at the muscle belly level were disrupted minimally. Supramaximal stimulation of ulnar and median nerves excited all palmar muscles in the antebrachium maximally and simultaneously. Tendon forces were measured for different positions of the ECR-FCU insertion. PL was kept at a constant length.

RESULTS: X-ray images indicated that in two of the three muscles the distance between the markers was unaltered up to 3 weeks after the surgery, indicating a stable tendon-to-tendon suture. Excitation of FCU resulted in wrist extension. Repositioning the ECR-FCU complex in distal direction, which corresponds to wrist flexion, increased passive and active forces exerted at their distal tendons. PL force decreased if the ECR-FCU complex was changed from low (zero active force) to high length (e.g., by 9-31% at optimum length). Maximal active ECR-FCU force was 40-67% of optimal FCU force (i.e., 3.41 ± 0.26 N; assessed in intact forelimbs of rats with similar body mass). However, active force was small in the *in vivo* operating length range. Anatomical dissection revealed stiff connective tissue linkages between FCU muscle and surrounding structures.

CONCLUSIONS: These results indicate that the tendon transfer successfully altered the mechanical effect of FCU from wrist flexion to wrist extension. However, the length-force characteristics suggest that the muscle can generate only minimal movements at the wrist. Besides by changes in extramuscular connective tissues (e.g., scar tissue formation), this may be explained by changes of muscle (e.g., an increase in the number of sarcomeres in series within muscle fibers) and/or tendon (e.g., a higher length). Further studies are required to investigate which factors during (e.g., tendon force and length during transfer) or after the tendon transfer (e.g., joint immobilization) affect these tissue adaptations.

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