GLIDING RESISTANCE OF FLEXION TENDON ASSOCIATED WITH CARPAL TUNNEL PRESSURE
Chunfeng Zhao, Anke M. Ettema, Lawrence J. Berglund, Kai-Nan An, Peter C. Amadio
Orthopedic Surgery, Mayo Clinic, Rochester, MN

Introduction: It is generally accepted that repetitive hand motion is a risk factor for carpal tunnel syndrome (CTS), a compression neuropathy of the median nerve at the wrist. It is clear that increased carpal tunnel pressure alters median nerve function in a dose-dependent manner. Patients with CTS may have activity related carpal tunnel pressures of 100 mm Hg or more, as compared to the normal resting pressure of roughly 5 mm Hg. While the frictional force between flexor tendon and surrounding tissues in the increases with the wrist flexion, the relationship of frictional force to carpal tunnel pressure is unknown. The purpose of the current study was to investigate the gliding resistance of a representative tendon, the middle flexor digitorum superficialis (FDS) within the carpal tunnel with varying carpal tunnel pressure in a human cadaver model.

Materials and Methods: Eight fresh frozen human cadaver upper extremities were used. The FDS tendons of the second, third and fourth digits were exposed proximal and distal to the flexor retinaculum, maintaining the carpal tunnel region intact. The excursions of the FDS tendons from index, middle, and ring finger were measured during finger motion with the wrist in the neutral position. Then, the tendons were dissected from their distal attachments, and the index, middle, ring, and small fingers were amputated at the MCP joint level, leaving the flexor retinaculum intact. A custom-made external fixator was used to position the wrist in the neutral position.

The specimen was then mounted on the testing apparatus (Fig1). Load transducers were connected to the distal (F1) and proximal (F2) ends of the middle finger FDS tendon. The proximal ends of all three FDS tendons were connected to a mechanical actuator. A 2-Newton load was attached to each of the distal ends of three FDS tendons. A 1 N load was attached to each of the distal ends of the index, middle and ring finger FDP tendons, to maintain a minimal level of tension. A custom-made balloon was inserted dorsal to the FDP tendons to avoid direct contact with the FDS tendons during tendon gliding.

The FDS tendons were pulled proximally by the actuator against the weight at a rate of 2.0 mm/sec. This movement of the tendon toward the actuator was regarded as flexion. The actuator movement was then reversed, causing the tendons to be pulled distally by the distal 2N load. This movement of the tendon toward the load was regarded as extension. In simulating making a fist motion, the excursion of the FDS tendon with the least excursion was used as the excursion for all three tendons. Therefore, during testing, all FDS tendons moved within a physiological range. The FDS gliding resistance was measured in the following six conditions, 1) before the balloon insertion; 2) balloon with 0 mmHg pressure; 3) 30 mmHg; 4) 60 mmHg; 5) 90 mmHg; 6) 120 mmHg.

Mean gliding resistance (MGR) was calculated based on the force values measured throughout the range of excursion by the following formula: \( \frac{F2-F1}{2} \) as \( F1 = F1c = 2 \) Newton (the applied load), the MGR formula simplifies to \( (F2-F2e)/2 \). Data obtained from the gliding tests were analyzed using one factor repeated ANOVA to assess whether there were measured differences among the different groups, followed by a Tukey-Kramer post-hoc test for individual comparisons. A p<0.05 significance level was used in all cases.

Results: The MGR of the middle FDS tendon without and with balloon with 0 mmHg was significantly lower than that of the 60, 90, and 120 mmHg groups (p<0.05). The MGR in the 120 mmHg group was significantly higher than all the other groups (p<0.05) (Fig 2).

Discussion: This study demonstrates a relationship between flexion tendon gliding resistance and carpal tunnel pressure. The middle finger FDS gliding resistance increased as carpal tunnel pressure increased, especially with pressures over 60 mmHg, a level which is often reached in CTS patients. With repetitive motion of flexor tendons, this small amount of increased gliding resistance may affect the physiology of the sub-synovial connective tissue (SSCT) leading to the SSCT thickening which is often observed in CTS patients. Increased carpal tunnel volume due to thickening of the SSCT may further elevate the carpal tunnel pressure, leading to a vicious cycle.

Acknowledgements: This study was funded by grants from NIH (NIAMS AR49823).


Fig 1. Testing apparatus. 1. Actuator; 2. Load transducer (F2); 3. Specimen; 4. Three FDS tendons; 5. Retinaculum; 6. Three FDP tendons; 7. Load transducer (F1); 8. Three 2-Newton weights attached to the FDS tendons; 9. Three 1-Newton weights attached to the FDP tendons; 10. External fixator. 11. Air balloon inside carpal tunnel with connected catheter; 12. Manometer.

Fig 2. Significance (p<0.05) was indicated with different letter (a < b < c < d).