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FINGER FLEXOR TENDON EXCURSION DURING COMPUTER KEYBOARDING

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INTRODUCTION

Previously our laboratory demonstrated that a continuous one-hour keyboarding assignment caused acute changes in the ultrasonographic measures of the median nerve.[1] We also attempted to correlate these changes to a variety of contributing factors, such as individual features, as well as certain biomechanical variables. In this study, our objective was to quantify the amount of tendon travel as a function of keyboarding and investigate the effects of tendon travel on the median nerve ultrasonographic measures.

Carpal tunnel is a narrow pathway on the palm side of the wrist. It contains the median nerve and the flexor tendons that bend the fingers. The flexor digitorum profundus (FDP) and flexor digitorum superficialis (FDS) muscles of the forearm are two major finger flexor muscles and are the only muscles involved in flexion of all four fingers. Tendons of both the FDS and FDP are contained within a common sheath passing through the carpal canal. Several authors have reported that the nerve is compressed by thickening of the flexor tendon sheaths.[2,3] In so many as 87% of the carpal tunnel syndrome (CTS) cases, Yamaguchi et al.[2] found greater fibrosis and edema in the tendon sheaths compared with controls. Moore et al.[3] used tendon excursion as one of the indicators of a repetitive and forceful task using a hand tool. Sommerich quantified the biomechanics of typing for 25 experienced computer users.[4] The average tendon travel, normalized to 1 hour of continuous typing, ranged from 30 to 59 m/h.

In this study, we adopt and modify a mathematical model of flexor tendons in which we can integrate individual anthropometric measurements and obtain an estimate of tendon displacement as a function of fingers and wrist angles during keyboarding. Furthermore, we investigate the correlation between the tendon travel and acute changes in the median nerve ultrasound measures as a result of continuous keyboarding.

MATERIALS AND METHODS

Data Collection

A convenience sample of forty volunteers who were screened for any hand symptoms or prior history of median neuropathy participated in this study. All participants self-reported that they were expert typists (i.e., typing at least 40 words per minute), used a keyboard at least four hours a day, three days a week, and typed using all digits. Ultrasound images of the carpal tunnel, with primary emphasis on the median nerve, were collected at the distal radius and the pisiform levels. The baseline images were collected prior to the keyboarding task and served as a reference for comparing the post-keyboarding measures in order to quantify acute changes of the median nerve. An interactive MATLAB image analysis program was used to make measurements of the median nerve in the ultrasound images.[1]

Kinematics data were collected using an OPTOTRAK motion measurement system positioned above a computer workstation. The hand, wrist, and finger movements were derived from the tracking of 18 active markers positioned on the dorsal surface of the dominant hand. Data were collected at 60 Hz during the four 1-minute intervals. Marker data collected were used to define the fingers and wrist angles.

Tendon Travel Calculations

In order to calculate tendon travel during keyboarding, the modified Armstrong and Chaffin model[5] which was previously developed and tested for similar applications[6,7] was used. This model allows calculating tendon excursion as a function of not only joint angles, but specific geometrical variables of the hand and fingers. It also takes wrist angles into account as well as the metacarpo-phalangeal and proximal and distal interphalangeal angles. This model is applicable to both FDP and FDS tendons, and has been tested to determine if it could account for all differences among tendon-joint displacement relationships of different hands and fingers.

Tendon displacement was calculated as a function of flexion angle and joint thickness for PIP and MCP joints of the index, middle, and ring finger, as well as wrist flexion and thickness, over four one-minute periods of keyboarding (Figure 1). The difference between positions at two consecutive time points was considered tendon travel at the second time point (Figure 2). Tendon travels were then averaged and the values of each segment (i.e., wrist, MCP, and PIP) for each finger were added and multiplied by 60 to estimate cumulative tendon travel (CTT) for the corresponding finger in one hour.

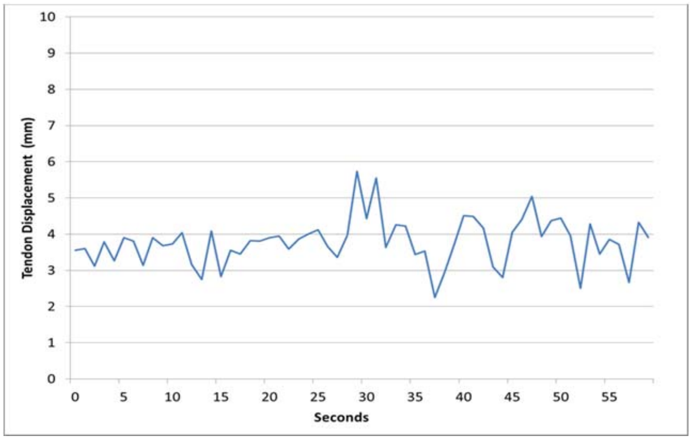

Figure 1: Exemplar graph depicting the FDP tendon displacements as a result of wrist flexion

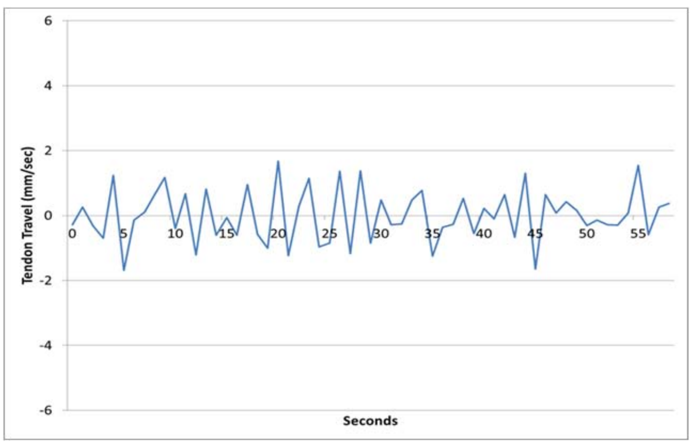

Figure 2: Exemplar graph depicting the FDP tendon travel as a result of wrist flexion

RESULTS

The tendon travel of FDP and FDS were found to be significantly correlated with a correlation coefficient of 0.99 across all fingers and wrist. As such, only tendon travel for FDP was used for the correlation analyses and linear regression models. Mean values and standard deviations for average, peak, range, and cumulative tendon travels for the FDP are shown in Table 1.

Pearson Correlation was used to investigate correlation between the median nerve ultrasound measures and cumulative tendon travels. This analysis found significant positive correlation only between CTT and the flattening ratio at the baseline. The middle finger CTT was also significantly correlated to the flattening ratio at the 30-minute time point.

Table 1: Mean and standard deviation (SD) of peak, average, range, and cumulative tendon travel as a result of the index, middle, and ring fingers flexion and wrist flexion during keyboarding

Tendon Travel Mean ± SD		Peak (mm/sec)	Average (mm/sec)	Range (mm)	Cumulative (m/hour)
Index	PIP	4.23 ± 1.81	1.22 ± 0.47	4.21 ± 1.80	13.42
	MCP	5.02 ± 1.37	1.45 ± 0.41	4.99 ± 1.36	
Middle	PIP	4.52 ± 3.51	1.13 ± 0.46	4.50 ± 3.51	12.46
	MCP	4.65 ± 2.60	1.26 ± 0.40	4.62 ± 2.60	
Ring	PIP	7.61 ± 6.85	1.43 ± 0.62	7.58 ± 6.85	15.25
	MCP	9.36 ± 11.04	1.76 ± 1.48	9.33 ± 11.04	
Wrist Flexion		4.64 ± 7.99	1.12 ± 1.75	4.62 ± 8.00	

DISCUSSION

In this study, we used an established methodology to calculate tendon travel as a result of flexion of the wrist and index, middle, and ring fingers during keyboarding. Using keyboarding kinematic data and anthropometric measurements, we were able to modify the regression models that have been previously tested by empirical data. This helped us include individual differences in our calculation to obtain results that reflect the effects of geometrical and biomechanical variables among population. The results of this study were consistent with those that have previously reported in biomechanical literature. In particular, our estimation of FDP and FDS tendon travel was found to be in the range that has been reported in literature. Specifically, the cumulative tendon travel for one hour of continuous typing was estimated to range from 12.5 m to 15.3 m.

The tendon travel calculations were followed by correlation analyses, which revealed several significant correlations between the tendon travel and acute changes in the median nerve measures. Furthermore, the multiple linear regression models that combined several individual and biomechanical variables were constructed to predict the changes in median nerve measures during keyboarding. In fact, one of these models demonstrated significant contribution from the wrist average tendon travel in predicting changes in the median nerve flattening ratio during keyboarding. Such a correlation suggests that tendon travel may play a major role in the median nerve pathophysiology.

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REFERENCES

1. Toosi KK, et al. Am J Ind Med, 2011 Nov; 54(11):826-33.
2. Yamaguchi DM, et al. Minnesota Medicine. 1965 Jan; 22–23.
3. Moore JS. Occup Med. 1992 Oct; 7(4):741-63.
4. Sommerich CM, et al. J Occ Rehab 1996; 6:33-55.
5. Armstrong TJ and Chaffin DB. J Biomech. 1978; 11:119-28.
6. Nelson JE, et al. Clin Biomech. 2000 Aug; 15(7):489-98.
7. Treaster DE and Marras WS. Clin Biomech. 2000 Aug; 15(7):499-503.