# NET TORQUES VARY ACROSS MCP JOINTS DURING A TEXT TYPING TASK

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## INTRODUCTION

The most consistent finding among epidemiologic studies evaluating computer use and musculoskeletal outcomes is the association between hours keying and hand/arm health outcomes [1]. While peak forces applied to the keyboard are low (~3 N [2]), keying is a highly repetitive activity where a proficient typist may strike the keys over 20,000 times per hour.

Previous studies have measured keyboard reaction forces during typing [2] and dynamic joint loads during single finger tapping [3], however, no study to our knowledge, has characterized loads of the fingers and upper extremity joints during multi-finger typing. Quantifying finger and upper extremity joint dynamics during typing will help inform the design of keyswitches and keyboards aimed at reducing the biomechanical loads associated with computer use.

In this preliminary study, we assessed individual keystrike forces and the net external torques across the first 4 metacarpal-phalangeal (MCP) joints during a continuous multi-finger typing task. We also evaluated how key-strikes from each digit affect joint torques at the wrist.

## METHODS

Three participants (2 female, 1 male) completed a one minute typing task. Participants completed the task on a standard keyboard with the "J" key set at elbow height when seated. Informed consent was obtained, and all protocols were approved by the Harvard School of Public Health Institutional Review Board.

A six degree of freedom force transducer (F/T Sensor Gamma, ATI Industrial Automation, Apex, USA) secured underneath the keyboard measured force and moment at 100 samples/s.

An infrared 3-D motion analysis system (Optotrak Certus, Northern Digital, Waterloo, Canada) tracked upper extremity trajectories at 100 samples/s. Modeling the trunk, arm, forearm and hand as rigid bodies, the location of specific bony landmarks, relative to clusters of three infrared light emitting diodes (IREDs), were tracked and used to define segment local coordinate systems and joint centers.

A local coordinate system for the thumb was defined using 3 IREDs, one fixed to the thumbnail and 2 fixed to a rigid plate. The rigid plate was secured to the 1$^{st}$ MCP, such that one IRED was directly over the joint and the second was lateral to it and perpendicular to the long axis of the thumb. The thumb joint center was assumed to be at the IRED placed directly over the 1$^{st}$ MCP.

Local coordinate systems for the index, middle and ring fingers were defined using IREDs secured to each fingernail and locations of the 2$^{nd}$ and 5$^{th}$ MCP, tracked as bony landmarks associated with the hand IRED cluster. Joint centers for each digit were calculated as a proportion of the distance between the 2$^{nd}$ and 5$^{th}$ MCP.

Individual finger key-strikes were identified using center of pressure (COP) values and the 3D location of each fingertip IRED. COP was calculated using force and moment data, assuming all moment data were due to off-axis loads. Key-strikes were defined as periods where force exceeded the 60$^{th}$ percentile of all applied forces. A key-strike was attributed to a finger when its IRED was the closest to the COP and it was at least 25% closer than any other IRED.

Peak force, COP and segment kinematics at peak force during each key-strike were then input into an inverse dynamics link segment model to calculate joint torques at the MCP of the digit striking the key. Torques at the wrist were also calculated for each key-strike.

## RESULTS

From a one minute typing task, an average of 16 to 35 key-strikes were identified for each finger (Table 1). Peak key-strike forces were greatest for the middle finger, and lowest for the ring finger. Forces were similar between the thumb and index fingers.

| | Thumb | Index | Middle | Ring |
|---|---|---|---|---|
| Key-strikes | 35 (2) | 26 (3) | 16 (13) | 20 (8) |
| Force [N] | 1.6 (0.3) | 1.6 (0.1) | 1.7 (0.2) | 1.4 (0.2) |
| Torque [Nmm] | 72 (22) | 77 (12) | 96 (11) | 76 (10) |

**Table 1.** Mean (SD) number of identified key-strikes, peak force and MCP joint torque magnitude during key-strikes with the associated digit (n=3).

Torque magnitude was greatest at the middle MCP and smallest at the thumb MCP (Table 1). Torque at the thumb MCP was shared across extension and abduction, while torques at the index, middle and ring MCPs were primarily in extension (Figure 1). Adduction and pronation MCP torques were largest for the thumb, while extension torques were greatest for the middle finger.

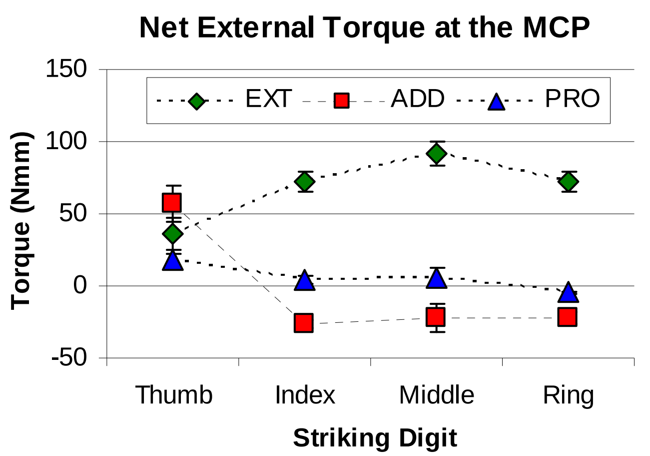


**Figure 1.** Mean net external torques at the MCP joints during key-strikes with the first four digits of the hand. Positive values indicate torques in extension (EXT), adduction (ADD) and pronation (PRO). Vertical bars indicate +/- 1 SD, n=3.

Flexion torque at the wrist (negative extension values) was greatest when fingers were not striking the keys, while suppination torque (negative pronation values) was greatest during thumb key-strikes (Figure 2). As key-strikes moved laterally from the thumb to the middle finger, flexion and suppination (negative pronation values) torques at the wrist decreased while adduction torques increased.

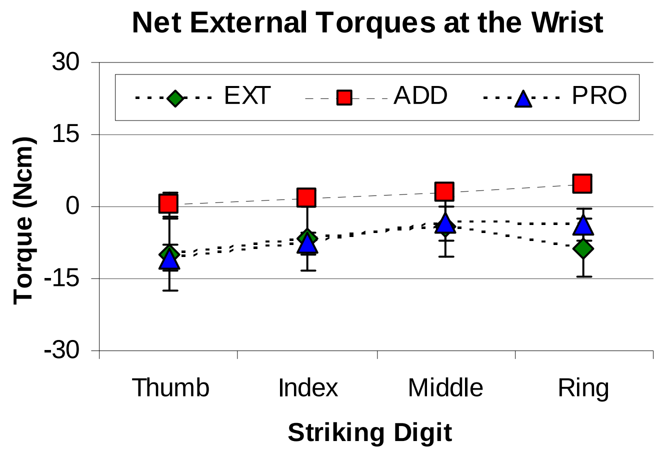


**Figure 2.** Mean net external torques at the wrist joints during keystrikes with the Thumb, Index Middle and Ring finger as well as during no keystrikes (None) . Positive values indicate torques in extension (EXT), adduction (ADD) and pronation (PRO).

## DISCUSSION

This is the first study to characterize individual key-strike forces and torques at the MCP joints during a text typing task. Our results indicate joint torques at the MCP vary by the digit striking the keys. Furthermore, fingers strikes affect wrist torques differentially. These findings suggest keyboard design features, such as keyswitch make force and split keyboard angles should take into account which fingers will be striking the keys.

Finally, in addition to evaluating keyboard design features, the methods reported here can also be used to characterize hand and finger functionality among computer workers with disorders such as osteoarthritis.

## ACKNOWLEDGEMENTS

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## REFERENCES

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