Are there Differences in Typing Performance and Typing Forces between Short and Long travel Keyboards?

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With keyboards gravitating towards thinner designs (shorter key travel distances) it is important to understand how these short travel keyboards may affect typing performance, typing forces and operator comfort. Using 15 subjects (7 males, 8 females), we wanted to determine whether there were differences in typing performance when computer operators typed on three keyboards with the same activation force (0.6 N) but with different key travel distances (2.0mm, 2.5mm and 4.0mm). During a 15 minute typing session on each keyboard, typing performance (speed and accuracy), typing forces and perceived fatigue ratings were measured. There were no differences in typing speed ($p = 0.39$), typing accuracy ($p = 0.33$) or keystroke durations ($p = 0.15$) across the three keyboards. However, typing force differences were measured ($p < 0.003$) with the longest travel keyboard (4.0mm) having higher mean and peak forces compared to the shorter travel keyboards (2.0 and 2.5 mm). These findings indicate that there is no apparent detriment in physical exposure or typing performance when using shorter travel keyboards.

INTRODUCTION

Computer keyboard characteristics may increase computer users' risks for developing Work-Related Musculoskeletal Disorders (WMDs). A keyboard's height, key displacement, tactile feedback and activation force can affect repetition, wrist postures, and forces applied whilst typing, risk factors that may be related to developing arm and neck Cumulative Trauma Disorders (Radwin and Ruffalo 1999; Lee et al. 2008).

The keyboard's activation forces and travel distances primarily determine a keyboard's force-displacement characteristics (Gerard et al. 1999; Radwin and Ruffalo 1999). Since users may type 200,000 keystrokes in a day, small changes in the amount of force required to activate a key can result in significant increases in the forces applied by users (Armstrong et al. 1994). Altering the travel distance affects intrinsic and extrinsic hand muscle activity (Lee et al. 2008) and the type of switch under keys affects force damping and key stiffness. These characteristics can affect user muscle activity and applied force (Nagurka and Marklin 2005; Rempel et al. 1997; Gerard et al. 1999; Lee et al. 2008).

Although there has been research into how altering activation forces can affect finger and arm muscle activity or applied force during tapping tasks, there is a lack of research into how different keyboard switch mechanisms and travel distances affect applied typing forces, comfort and productivity during typing.

Computer keyboard characteristics affect risk factors associated with developing cumulative trauma disorders. Changes in key switch type or travel distance alter the key force-displacement characteristics, which affect typing forces, muscle activity, and wrist posture. Switch mechanisms affect typing forces, muscle activity, and may affect wrist extension, which in part determines intra-carpal tunnel pressure. As occupational use of laptop and short-profile keyboards becomes more prevalent, it is important to understand how characteristics of these keyboards may affect the risks of users developing upper extremity CTDs.

The goal of this study was to determine whether key travel distance influence typing forces, typing productivity and subjective measures of keyboard preference, comfort and fatigue. Based on previous research, it was hypothesized that keyboards with

shorter displacement distances will have increased applied forces when compared with keyboards with longer displacement distances.

METHODS

Fifteen subjects (7 male, 8 female) who were all right hand dominant; self-reported touch typists of > 40 wpm; and had no history of trauma or pain in the arms, wrists, or hands participated in the study. The University of Washington Human Subjects Institutional Review Board approved all procedures and subjects gave their informed consent before participating in the study.

The experimental task consisted of having subjects type 15 minutes each on three keyboards with the same activation force (0.60 N), but different travel distances: 1) a keyboard with 4.0 mm of key travel (Model SK-8115; Dell Inc; Round Rock, TX), 2) a keyboard with 2.5 mm of key travel (Model FQ481AA; Hewlett Packard Inc.: Palo Alto, CA) and 3) a keyboard with 2.0 mm of key travel (Model A1243, Apple Inc; Cupertino, CA). The 4.0 mm travel keyboard had rubber dome/membrane switches and the shorter travel keyboards scissor switches. As subjects typed, their typing speed and accuracy were measured by a software program (Typing Workshop Deluxe Version 6.20, ValuSoft, Minneapolis, MN).

Before starting the typing task, the chair, table, and monitor were adjusted to each subject in accordance with ANSI/HFES 100-2007. The typing task consisted of typing text from a novel for two, 7.5 minute blocks. After the 15 minute typing session, subjects rated their perceived fatigue in the hands, wrists, shoulders, and neck using a visual analog form of a Borg CR-10 Scale (Borg and Borg 2002; McLoone et al., 2010). Subjects were given a rest period of at least 5 minutes between keyboards, which could be longer if subjects requested.

Figure 1. Side view of a keyboard sitting on top of the force platform.

As shown in Figure 1, in order to measure the applied finger forces during the typing tasks, the keyboards were placed on a force platform. Three hard rubber feet were placed on the bottom of the keyboard in a triangle to account for any surface irregularities in the bottom of the keyboards and act as mechanical filters.

The force platform consisted of a 36 cm x 18 cm x 0.79 cm aluminium plate mounted to six DOF force/torque load cell (Mini-40E; ATI Inc.; Apex, NC). As shown in Figures 1 and 2, a white plastic frame, slightly lower in height, surrounded the force platform. This white plastic frame created a flat work surface which compensated for the additional height of the force platform and protected the load cell from being exposed to any potentially damaging torques. A LabVIEW program (Version 8.6; National Instruments; Austin, TX) simultaneously measured the typing forces and the digital signal from the keyboard, indicating which key was depressedat 500 Hz.

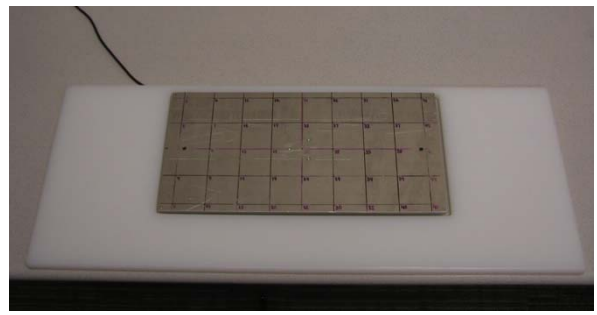

Figure 2. The force platform and the plastic frame that protected the force platform.

The downward, z-axis typing forces for each keyboard were analyzed using a LabVIEW program. The LabVIEW program analyzed the applied forces for each individually identified keystroke. The beginning of the keystroke was defined as when the downward force applied to the force platform exceeded 0.4 N and the end of the keystroke occurred when the force returned below 0.4 N. Using the individual identified keystrokes, mean forces, peak forces, the keystroke time tension product and keystroke durations were calculated. The keystroke time-tension product (KTTP) was the integrated area under a keystroke and had units of Newton-milliseconds (N-ms).

Using Repeated Measures Analysis of Variance methods, differences in typing speeds, typing accuracy, comfort and typing forces were analyzed in JMP (version 8.0; SAS Institute Inc.; Cary, NC). Differences were considered to be statistically significant when p-values were below 0.05. Statistically significant differences across the three

keyboards were analyzed using Tukey's test of Honestly Significant Differences.

RESULTS

Table 1 shows that there were no differences in typing speed (p = 0.39) or accuracy (p = 0.34) across the three keyboards. No trend was apparent in either typing speed or accuracy as a function of an increase or decrease in key travel distance.

Table 1. Mean (± SE) typing speed in word per minute and percent accuracy compared across the three keyboards (n = 15).

	Key Travel			
	2.0 mm	2.5 mm	4.0 mm	p-value
Typing Speed (WPM)	56.2 (±2.6)	55.5 (±2.5)	56.4 (±2.8)	0.39
Typing Accuracy (%)	91.9 (±0.9)	91.1 (±0.8)	91.9 (±1.0)	0.34

As can be seen in Table 2 there were significant differences in the peak forces applied to the keyboards (p < 0.001), the mean force (p = 0.0003) and the KTTP (p = 0.0006). The differences in keystroke durations did not reach significance (p = 0.15). The only consistent difference was the 4.0 mm travel keyboard had the highest mean, peak and KTTP forces and the longest keystroke durations. The 2.0 mm keyboard was intermediate with respect to all parameters and the 2.5 mm travel keyboard was the lowest.

Table 2 Mean (± SE) typing forces compared across the three keyboards (n = 15). Across rows, values that have different letters are significantly different.

	Key Travel			
	2.0 mm	2.5 mm	4.0 mm	p-value
Peak Force (N)	2.33 [a] (±0.1)	2.29 [a] (±0.08)	2.68 [b] (±0.11)	<0.0001
Mean Force (N)	1.13 [ab] (±0.04)	1.10 [a] (±0.04)	1.18 [b] (±0.03)	0.003
Keystroke Duration (ms)	112.1 (±3.9)	109.2 (±5.3)	115.2 (±3.6)	0.15
KTTP (N-ms)	142.5 [ab] (±7.9)	136.6 [a] (±9.3)	154.4 [b] (±7.6)	0.006

Table 2 shows that there were no differences in Borg CR10 rating in the hand (p = 0.45) and wrist (p = 0.13), a trend indicating a difference in the neck (p = 0.07) and differences in the shoulder (p = 0.03). There were consistent differences in the Borg CR-10 perceived fatigue ratings with the 4.0 mm travel keyboard having the highest ratings of perceived fatigue, the 2.5 mm travel keyboard having intermediate ratings and the 2.0 mm travel keyboard having lowest perceived fatigue ratings.

Table 3 Mean (± SE) changes in Borg CR-10 ratings across keyboards (n = 15). Across rows, values that have different letters are significantly different.

	Key Travel			
	2.0 mm	2.5 mm	4.0 mm	p-value
Neck	0.61 (±0.33)	0.71 (±0.33)	1.4 (±0.42)	0.07
Shoulder	0.69 [a] (±0.19)	0.77 [ab] (±0.24)	1.24 [b] (±0.33)	0.03
Wrist	0.62 (±0.23)	0.73 (±0.20)	1.1 (±0.33)	0.13
Hand	0.75 (±0.33)	0.93 (±0.21)	1.12 (±0.29)	0.45

DISCUSSION

No significant differences were found in typing productivity between keyboards, but there were differences in the applied typing forces across keyboards. Compared to the shorter travel (2.0 and 2.5 mm) keyboards, the applied typing forces and keystroke durations were highest with the longest travel (4.0 mm) keyboard. In addition, the changes in perceived fatigue paralleled the trends measured in the typing force data. The 4.0 mm travel keyboard had the highest ratings of perceived fatigue, the 2.5 mm travel keyboard was intermediate and the 2.0 mm keyboard had the lowest perceived fatigue ratings. These findings indicate that there is no apparent detriment in physical exposure, based on typing forces; and no difference detrimental effect on typing performance or perceived fatigue when using shorter travel keyboards.

The keystroke durations and typing forces observed in this study were in line with those reported by Martin et al. (1996). Keystroke duration and applied forces during typing appears to be a function of both keyboard switch mechanism (scissor or rubber dome) and travel distance. It was difficult to distinguish between the effects of switch mechanism and travel distance since there was no available long travel scissor switch keyboard or short travel dome keyboard available for use in the study. By using keyboards of a similar make and quality that only differ in their travel distance or switch mechanism and include more combinations of travel distance with switch mechanism, conclusions could be drawn as to which effects are related primarily to switch mechanism, travel distance, or a combination of both.

While this study looked at short travel distance keyboards similar to laptop keyboards, the study keyboards were not identical to laptop keyboards.

Future research could include laptop keyboards as well as keyboards with no displacement distance (i.e. touch screen keyboards). By including keyboards with no switches, the effect of tactile and auditory feedback could be better determined since auditory feedback would not come from the keyboard but from software that could be much more readily altered.

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REFERENCES

Armstrong, T., Foulke, J., Martin, B., Gerson, J., & Rempel, D. (1994). Investigation of applied forces in alphanumeric keyboard work. *American Industrial Hygiene Association Journal*, 55(1), 31-35.

Borg E, & Borg G. (2002). A comparison of AME and CR100 for scaling perceived exertion. *Acta Psychologica (Amsterdam)*, 109(2), 157-175.

Gerard, M., Armstrong, T., Franzblau, A., Martin, B., & Rempel, D. (1999). The effects of keyboard stiffness on typing force, finger electromyography, and subjective discomfort. *American Industrial Hygiene Association Journal*, 60, 762–769.

Lee, D., Kuo, P.-L., Jindrich, D. & Dennerlein, J. (2008). Computer keyswitch force–displacement characteristics affect muscle activity patterns during index finger tapping. *Journal of Electromyography and Kinesiology*, 19(5), 810-820.

Martin, B., Armstrong, T., Foulke, J., Natarajan, S., Klinenberg, E., Serina, E. & Rempel, D. (1996). Keyboard reaction force and finger flexor electromyograms during computer keyboard work. *Human Factors*, 38 (4),654–664.

McLoone H, Jacobsen M, Hegg C, & Johnson P. (2009). Design and evaluation of a curved computer keyboard. *Ergonomics*, 52(12), 1529 - 1539.

Nagurka, M., & Marklin, R. (2005). Measurement of stiffness and damping characteristics of computer keyboard keys. *Journal of Dynamic Systems, Measurement, and Control*, 127, 283-288.

Radwin, R., & Ruffalo, B. (1999). Computer key switch force-displacement characteristics and short-term effects on localized fatigue. *Ergonomics*, 42(1), 160-170.

Rempel, D., Serina, E., Klinenberg, E., Martin, B., Armstrong, F., Foulke, J. &Natarajan, S. (1997). The effect of keyboard keyswitch make force on applied force and finger flexor muscle activity. *Ergonomics*, 40(8), 800-808.