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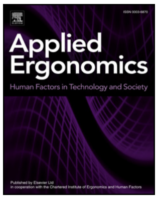

# Differences in typing forces, muscle activity, wrist posture, typing performance, and self-reported comfort among conventional and ultra-low travel keyboards

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ABSTRACT

This study investigated the relative impact of ultra-low travel keyboards on typing force, muscle activity, wrist posture, typing performance, and self-reported comfort/preference as compared to a conventional keyboard. In a repeated-measures laboratory-based study, 20 subjects were invited to type for 10 min on each of five keyboards with different travel distances of 0.5, 0.7, 1.2, 1.6 (ultra-low travel keyboards), and 2.0 mm (a conventional keyboard). During the typing sessions, we measured typing force; muscle activity in extrinsic finger muscles (flexor digitorum superficialis and extensor digitorum communis), shoulder (trapezius) and neck (splenius capitis); wrist posture; typing performance; and self-reported comfort/preference. While using the ultra-low travel keyboards, subjects typed with less force and wrist extension, and had more ulnar deviation (p's $<$ 0.0001) compared with conventional keyboard. However, these differences in typing forces were less than 0.5 N and less than 4° for both wrist extension and ulnar deviation. The general trend of data did not show any consistent or substantial differences in muscle activity (less than 2 %MVC) and typing performance ($<$ 5 WPM in speed; $<$ 3% in accuracy), despite the observed statistical difference in the finger flexors and extensors muscle activity (p's $<$ 0.19) and typing performance ($p < 0.0001$). However, the subjects preferred using conventional keyboards in most of the investigated self-reported comfort and preference criteria (p's $<$ 0.4). In conclusion, these small differences indicate that using ultra-low travel keyboards may not have substantial differences in biomechanical exposures and typing performance compared to conventional keyboard; however, the subjective responses indicated that the ultra-low keyboards with the shortest key travel tended to be the least preferred.

## 1. Introduction

Although the degree of association varies by studies, many previous studies have shown an association between computer keyboard use and upper extremity musculoskeletal disorders (MSDs) (Andersen et al., 2011; Bergqvist et al., 1995; Garza et al., 2012; Gerr et al., 2002). Among the possible risk factors, highly repetitive movements and awkward postures during computer keyboard typing are known to be risk factors for computer-related MSDs (Jensen et al., 2002; Joe Chang et al., 2009). Accumulation of micro trauma over long duration of time is known to be a underlying injury mechanism for computer-related MSDs in the upper extremities (IJmker et al., 2007; Jensen et al., 2002; Punnett and Wegman, 2004).

The physical characteristics of computer keyboards have found to affect biomechanical risks for musculoskeletal symptoms (Armstrong et al., 1994; Garza et al., 2012; Gerard et al., 1999; Kim et al., 2014; Lee et al., 2009; Radwin and Ruffalo, 1999; Rempel et al., 1997a, 1997b; Rempel et al., 1999). These studies have shown that key travel distance (Kim et al., 2014; Lee et al., 2009) and activation force (Armstrong et al., 1994; Gerard et al., 1999; Lee et al., 2009; Radwin and Ruffalo, 1999; Robert G. Radwin and Jeng, 1997) affect muscle activity, muscle fatigue and discomfort in the upper extremities.

As computer keyboards are gravitating towards thinner designs to increase portability and have a more visually appealing design, the key travel distances have substantially decreased from 4.0 mm (conventional detachable desktop keyboards) to less than 2.0 mm (ultra-low travel keyboards) (Sisley et al., 2017). Although changes in key travel distance can alter force-displacement characteristics that affect biomechanical risk factors and usability, there has been little research to investigate the effects of such ultra-low key travel distances on the

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biomechanical exposure measures and usability. Previous studies on the key travel distance were mainly on traditional keyboards with longer (≥2.5 mm) key travel distances (Lee et al., 2009; Radwin and Ruffalo, 1999). These studies showed that longer key travel was associated with decreased typing force (Lee et al., 2009; Radwin and Ruffalo, 1999). A few recent studies with current, shorter travel keyboards (~2.0 mm) showed that typing forces decreased as key travel decreased (Hughes et al., 2011; Hughes and Johnson, 2014; Kim et al., 2014). Hoyle et al. (2013) found that key travel distance was negatively correlated with typing performance, discomfort, and preference.

Due to the recent introduction of the ultra-low travel keyboards as part of laptop and tablet computers, and with designs gravitating towards thinner keyboards, there is relatively little research on the user comfort, usability, and typing performance associated with these ultra-low travel keyboards. Therefore, existing literature is not sufficient to determine MSD-related physical risks associated with ultra-low travel keyboards. To address this current research gaps, the goal of this study was to evaluate relative biomechanical exposures including typing forces, muscle activity on extrinsic finger muscles, shoulder and neck muscles, wrist postures, typing performance, self-reported comfort and preference between a conventional keyboard and a series of ultra-low travel keyboards.

## 2. Methods

### 2.1. Subjects

A total of 20 subjects (10 male and 10 female) were recruited to participate in this study via e-mail solicitations and printed flyers. The sex of the subjects was balanced to properly represent the general population. All subjects were touch typists who could type faster than 40 WPM and had no history of upper extremity musculoskeletal disorders. Eighteen subjects were right-handed and two subjects were left-handed. Their average (SD) age and computer experience was 29.5 (7.5) and 17.8 (6.1) years, respectively. The experimental protocol was approved by the University's Institutional Review Board and all subjects gave their written consent prior to their participation in the study.

### 2.2. Experimental protocol

Prior to the experiment, the chair and desk were adjusted based on anthropomorphic measures per ANSI/HFES standards (2007). Briefly, the chair was adjusted so that the subject's thighs were parallel to the ground and the cushion was adjusted such that the subject could fit two fingers between the end of the seat pan and their calf (Fig. 1). The keyboards were placed 7 cm from the edge of the work place and at the center of subjects' bodies. The workstation height was adjusted at 2 cm below sitting elbow height. Then, subjects had a practice session typing on a neutral, non-study keyboard to become familiar with the typing program interface used throughout the experiment (Mavis Beacon Teaches Typing Platinum – 25th Anniversary Edition; Broderbund Software Inc.; Eugene, OR, USA). To control the difficulty of the text, five chapters from Grimm's Fairy Tale stories were randomly selected for the typing tasks. These stories were rated as a 5.1–5.7 on the Flesch-Kincaid grade, which indicates that the text would be easily understood by an average twelve year old.

After the practice session, in a repeated-measures laboratory experiment, subjects typed for 10 min on each of the five keyboards that have relatively similar key activation force (0.5–0.6 N), key size (height x width = 15 × 15 mm), and key pitch (19 mm), with different key travel distance (Fig. 2). These keyboards included a conventional keyboard with a 2.0 mm travel distance (A1234; Apple; Cupertino, CA) and four ultra-low travel keyboards with key travel distances of 1.6 mm or less: 0.5 mm (MacBook; Apple; Cupertino, CA); 0.7 mm (Thin Touch; Synaptics; San Jose, CA); and 1.2 mm (Magic Keyboard; Apple; Cupertino, CA); 1.6 mm (Surface Typecover; Microsoft; Redmond, WA). The order in which the keyboards were used was randomized and counterbalanced to minimize any potential confounding due to keyboard testing order. Throughout the typing sessions, subjects were instructed to type with their normal typing speed and achieve a balance between accuracy and speed. Typing speed (words per minute) and accuracy (% key correctly typed) were measured by the typing program. Between typing sessions, a 5-min break was given to minimize residual fatigue effects of the previous keyboard testing condition. After typing on each keyboard, subjective comfort and preference ratings were collected using a slightly modified Likert scale questionnaire adapted from the ISO keyboard comfort questionnaire (ISO9241-410; 2008).

**Fig. 1.** Experimental setup.

### 2.3. Typing forces

Typing force were measured at a sampling rate of 500 Hz using a triaxial force platform that has been validated and used in previous studies (Kim et al., 2014; Kim and Johnson, 2012). The absolute mean force measurement errors over a 0–4 N range is less than 10% over the full area of the force platform (Kim and Johnson, 2012). The keyboards were located on the force plate so that the "H" key was positioned on the center of the force place. A polyoxymethylene frame was constructed surrounding the force plate at the same height to create a continuous work surface for the subjects. Subjects were instructed not to rest their hands and wrists on the force plate or keyboards to minimize potential for unwanted, static forces to be superimposed on the typing force data. The presiding experimenter observed the hand posture of the subjects through the experiments to minimize the potential for the superimposition of the unwanted static typing forces.

Prior to each typing session, the force plate was zeroed to offset the weight of the keyboard being tested. Perpendicular, downward, z-axis typing forces applied to the alphanumeric portion of the keyboard were investigated. A custom-built typing force program (LabVIEW, 2016b; National Instruments; Austin, TX, USA) identified and categorized the individual force profiles associated with each keystrokes by simultaneously saving the keyboards digital signals, which were unique to each key, parallel with the force data. Typically, the digital signal started when the forces applied to the keys were above 0.4N and ended when the forces descended below 0.4 N. In addition, to be considered as an individual keystroke, the force profile had to be between 16 and 250 ms long and the peak force had to occur in first half of force profile (Rempel et al., 1997a, 1997b). Typing force data was summarized using median and peak forces.