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Can digital signals from the keyboard capture force exposures during typing?

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Abstract. An exposure-response relationship has been shown between muscle fatigue and its effects on keystroke durations. Since keystroke durations can readily be measured by software programs, the method has the potential as a non-invasive exposure assessment tool. However, the software based keystroke durations may be affected by keyswitch force-displacement characteristics. Thus, this study used a force platform to measure the keystroke durations and compared them to software measured keystroke durations in order to determine whether the software based keystroke durations can be used as a surrogate force exposure measures. A total of 13 subjects (6 males and 7 females) typed for 15 minutes each on three keyboards with different force-displacement characteristics. The results showed that the software based keystroke durations were more sensitive to the keyboard force-displacement differences than the force based measures. Although the digital signal based keystroke durations depend on the force-displacement characteristics, the high correlation between the two measures indicated that the keystroke durations derived from the digital signal approximated the true force derived keystroke durations, regardless of the keyboard force-displacement characteristics. Therefore, the software based keystroke durations could be used as a non-invasive, surrogate force exposure measure in lieu of the more invasive actual force measurements.

Keywords: Computer use, musculoskeletal disorders, exposure assessment

1. Introduction

Intensive computer use has been associated with musculoskeletal disorders (MSDs) in the upper extremities [1, 2]. An exposure-response relationship has been shown between muscle fatigue and its effect on keystroke duration, and Chang et al. [1] proposed that temporal changes in keystroke durations may be an objective surrogate measure of muscle fatigue.

Keystroke durations can be measured by either a software program or a force platform mounted under the keyboard. Force platforms have been used to objectively assess typing force exposures including force, frequency, and duration of keystrokes [3-5]. The applied finger force profiles collected from force platforms provide actual force exposure information and keystroke durations which are not dependent on keyswitch design. However, it may not be appropriate to use a force platform in field studies due to its invasiveness and cost.

Other studies have used software programs to measure keystroke durations [1]. Since keystroke duration can readily be assessed using software programs installed on the operator's computer, the method has the potential as a simple, cost effective, non-invasive exposure assessment tool. However, the software based keystroke durations measured by the digital ON/OFF signal when a key is pressed and released may be affected by keyswitch force-displacement characteristics such as key activation force, travel distance and the electromechanical make-point when the key is pressed and released, whereas those measured by force platforms are not affected by the electromechanical differences in keyswitch designs.

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Therefore, using keyboards with different force-displacement characteristics, this study used a force platform to measure the keystroke durations directly from individual keystroke force profiles and compared them to software measured keystroke durations. The purpose of the study was to determine whether the software measured keystroke durations derived from the digital signal could be used as a non-invasive, surrogate force exposure measure in lieu of the invasive actual force measurements.

2. Methods

2.1. Subjects

Through e-mail solicitations, a total of thirteen subjects including 6 males and 7 females were recruited to participate in this study. All participants were right-handed touch typists with no history of upper extremity MSDs. The experimental protocol was approved by the Human Subject Committee at the University of Washington, and all subjects provided their written informed consent before the experiments.

2.2. Experimental design

The experimental task consisted of having subjects type for 15 minutes each on the three keyboards which were mounted on top of a thin force platform. The workstation was adjusted based on the subject's anthropometry in accordance with ANSI/HFES 100-2007. The chair was adjusted so the subject's feet rested firmly on the floor. With subjects relaxing their shoulders, resting their arms comfortably at their side and forming a 90 degree angle at the elbow, the height of the workstation was adjusted so the table height was set at approximately 2 cm below elbow height. The monitor was placed at arm's reach with the top of the viewing portion of the screen just below eye level and the keyboard had the spacebar centered on the subject's body.

The three keyboards tested, which had different keyswitch force-displacement characteristics, included: 1) a keyboard with 4.0 mm of key travel, 2) a keyboard with 2.0 mm of key travel and 3) a keyboard with 1.8 mm of key travel. The keyboard with 4.0 mm travel distance had rubber dome switches whereas the keyboards with 2.0 and 1.8 mm travel distance had scissor switches; the activation forces on all the keyboards were 0.6 N. The order of keyboard use was counterbalanced to minimize any potential confounding due to keyboard testing order.

During the typing tasks, keystroke durations from the individual keystroke profiles measured from the force platform and from the digital signals from the keyboard were simultaneously collected at 500 Hz.

2.3. Data analysis

Repeated measures ANOVA methods were used to determine whether there were differences in keystroke durations measured by digital keystroke signals and applied individual keystroke forces. In addition, linear regression methods were used to determine how well the digital-signal-based keystroke durations approximated the force based measures.

3. Results

The digital signal based keystroke durations from the 1.8, 2.0, and 4.0 mm travel keyboards were 125.4 (± 5.7), 115.7 (± 5.2), and 88.4 (± 3.2) milliseconds, respectively. The force based keystroke durations of the same keyboards were 114.6 (± 6.7), 105.1 (± 5.8), and 108.9 (± 4.4) milliseconds, respectively. The differences between the digital and force based measures on 1.8, 2.0, and 4.0 mm travel keyboards were 10.8 ($p = 0.02$), 10.6 ($p = 0.02$), and 20.5 ($p < 0.0001$) milliseconds, respectively. According to the results, the digital signal based keystroke durations showed more substantial differences than the force based measures. Despite the significant differences, the digital signal based keystroke durations were highly correlated with the force based measures (Table 1).

Table 1

Linear fits and Pearson's correlations between the keystroke durations measured from digital signals (x) and applied finger forces (y) on 1.8, 2.0 and 4.0 mm travel keyboard, respectively [n = 13].

Keyboard	Linear regression equation	R^2	P-value
1.8 mm	$y = 1.04x - 16.07$	0.89	< 0.0001
2.0 mm	$y = 0.94x - 4.10$	0.84	< 0.0001
4.0 mm	$y = 1.10x + 11.95$	0.84	0.0002

4. Discussion and conclusion

Using keyboards with different keyswitch force-displacement characteristics, the present study determined whether there was an association between keystroke durations measured from applied finger force profiles and those measured form the keyboard's digital signal.

The results showed that the differences in the force based keystroke durations between keyboards were smaller than differences measured using the digital signals from the keyboard. This is not surprising because the applied force profiles were not affected by the electromechanical differences in keyswitch designs and subject to the mechanical artifacts when measuring typing force (e.g. mechanical vibrations).

Although the keystroke durations measured by the digital signals depend on the force-displacement characteristics of the keyboard, the high correlation between the two measures (Table 1) indicates that the keystroke durations derived from the digital signal approximate the true force derived keystroke durations, independently of the keyswitch force-displacement characteristics.

Therefore, for field studies, the digital signal based keystroke durations, which can be readily measured by software programs installed on the user's computer, can be used as a surrogate, non-invasive force duration measure in lieu of the more complicated, expensive and invasive force platform derived measurements.

The limitation of basing keystroke force duration measurements on the digital signal is the loss of being able to measure the actual peak and mean force exposures; the gain is the simplicity, low cost and ability to collect large samples for epidemiological purposes.

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