Electromyography & Portable Computing Devices: What Forearm Muscles Should be Measured?

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Portable computing devices have become more lightweight and mobile due to changes in the hardware of the devices. In many cases, hardware keyboards are being replacing virtual keyboards, raising concerns on changing ergonomic exposures as, for example, muscle activation patterns may vary with virtual keyboard use. The objective was to identify active forearm muscles across select computing devices. Twenty participants completed a single test session in which seven forearm muscles were evaluated using surface EMG whilst they typed on two portable computing devices (netbook and slate computer) for 5 minutes apiece. Mean normalized EMG was analyzed and indicated that slate computers resulted in significantly lower muscle activation levels than netbooks. The extensor carpi radialis, extensor carpi ulnaris, extensor digitorum communis had the highest muscle activation levels for both the slate and netbook computers. This indicates that the same muscles should be studied for both slate and netbook computers.

INTRODUCTION

There is a trend in the development of electronic devices to create devices that are more compact and portable. One way that developers accomplish this is by altering the hardware of the devices, specifically the keyboard. The modification can take one of two forms: reduction in size of the hardware keyboard and/or replacing a hardware keyboard with a virtual keyboard. This alteration allows for devices to be highly functional and more lightweight; thus the devices become more portable.

Many computer users are embracing these new portable devices. It is estimated that between the years of 2010 and 2016, over 290 million slate computers will be sold worldwide (Melanson, 2011). Slate computers are an example of a class of devices that have opted to substitute the virtual keyboard for the traditional hardware keyboards.

Virtual keyboards are very different from hardware keyboards, because for the most part they are devoid of tactile feedback. With traditional hardware keyboards, users gain information about key activations and hand location based on the feedback they receive during the data entry process or the feel of the keys. For virtual keyboards, this information is removed and users are more reliant on visual information to help them to complete tasks, potentially altering their typing behavior or placing more strain on specific muscles. Prior studies have shown that performance is degraded when typing on virtual keyboards resulting in significantly slower typing speeds as compared to hardware keyboards (Kim, Aulck, Bartha, Harper & Johnson, 2012; Werth & Babski-Reeves, 2012).

Typically for the majority of typing and data entry studies, two or three forearm muscles are selected to be assessed for each study. Previously, the extensor digitorum communis (Jensen, Borg, Finsen, Hansen, Juul-Kristensen & Christensen, 1998; Lin, Liang, Lin & Hwang, 2004), extensor carpi radialis (Dennerlein & Johnson, 2007), extensor carpi ulnaris (Dennerlein & Johnson, 2007; Gilad & Harel, 2000; Jensen, et al., 1998; Simoneau, Marklin & Berman, 2003), flexor carpi radialis (Dennerlein & Johnson, 2007; Simoneau, Marklin & Berman, 2003), flexor carpi ulnaris (Dennerlein & Johnson, 2007; Gilad & Harel, 2000; Simoneau, Marklin & Berman, 2003), and the palmaris longus (Keir & Wells, 2002) have been evaluated when assessing muscle activity levels during typing tasks. While these muscles all have a role in typing tasks, it is not typically feasible to study each of these muscles for every typing study. Therefore, it is necessary to determine which muscles are the most active during typing to aid in the design of future studies of portable computing devices.

EMG research has provided a wealth of information about the ergonomic risks associated with typing on traditional keyboards and will be an integral part of assessing the potential risks that virtual keyboards pose. However, if there is a change in typing behavior, there is the potential that there is also going to be a change in the degree to which muscles are activated in the process.

The objective of this research has two parts. The first objective was to assess if there was a difference in the muscle activation levels based on computing device (netbook computer compared to a slate computer) used during typing tasks. The second objective of the study was to ascertain which muscles should be studied when assessing the ergonomic risks of slate computing devices.

METHODS

Participants

Twenty participants (10 males, 10 females) were recruited from an undergraduate Engineering Economy class at Mississippi State University. The average age of the participants was 21.35 years (SD = 5.41). Participants received course credit for participating in the study.

Experimental Design

A within subjects design was used to test for the main effect of computer type on muscle activation levels. To minimize any effects of order of exposure, exposure to computing devices was counterbalanced. Each task was performed for 5 minutes separated by a 2 minute rest period, which is further described below.

Independent Variables

The independent variable for this study was computer type (2 levels). The computers used in this study were a netbook (HP Mini 210-2190NR) and slate computer (Adam Tablet running Android 2.2).

Dependent Variables

Surface electromyography (EMG) was used to quantify muscle activation levels for different forearm muscles. The Noraxon 1400A system was used in the data collection. EMG measurements were taken from the brachioradialis (BR), extensor carpi radialis (ECR), extensor carpi ulnaris (ECU), extensor digitorum communis (EDC), flexor carpi radialis (FCR), flexor carpi ulnaris (FCU), and palmaris longus (PL) using Ag/AgCl pregelled bipolar disposable electrodes. Measurements were taken on both the right and left side simultaneously. Prior to the application of the electrodes, the skin was shaved, abraded and then cleaned with alcohol . Electrodes were placed in accordance with Perroto (2011) (Table 1). Electrode leads were secured to the skin with tape to minimize noise. Interelectrode distance between the electrodes was set at 2.5 cm. The data was collected at 1000 Hz. EMG signals were hardware amplified, band pass filtered (10-500 Hz), RMS converted (110 ms time constant) and A/D converted.

Table 1. Electrode placement

Muscle	Electrode Placement
BR	Midway between the biceps tendon and lateral epicondyle along the flexor crease
ECR	Two fingerbreadths distal to the lateral epicondyle
ECU	Just above the shaft of the ulna
EDC	A third of the way down the forearm at the midpoint between the radius and ulna
FCR	Three to four fingerbreadths distal to the midpoint of the line connecting the medial epicondyle and biceps tendon
FCU	Two fingerbreadths volar to the ulna at the junction of the upper and middle thirds of the forearm
PL	Junction of the upper and middle thirds of a line joining the medial epicondyle and the middle volar surface of the wrist

After stabilization of the electrodes (10 minutes), a multimeter was used to measure signal impedence. If the reading was greater than 10 kOhms then the electrodes were removed and preparation procedures repeated. Immediately following, a single maximal voluntary contraction (MVC) was collected for each arm separately. Participants sat in standard typing position (upper arms resting along their sides, lower arms flexed 90 degrees at the elbow and palms facing a desk surface) and performed a grip strength exertion (grip the handle as hard as they can) on a standard dynamometer without moving the arms. MVCs were measured using a 5-second ramp-up, rampdown procedure. A minimum of three, 5-second trials with a 30-second rest period between exertions were performed.

Experimental Task

The experimental task consisted of typing for 5 minutes using standard word processing software (ex. Microsoft Word). Text from a Human Resources textbook was used to minimize the likelihood that participants would be familiar with the task. Also, all the text selections from the book were at the same reading level.

Procedures

Participants completed a one hour testing session. First, participants were provided with a verbal and written description of the research, its objectives, and completed informed consent documents approved by the Mississippi State University Institutional Review Board prior to any data collection. Participants completed a custom demographic questionnaire. Then, EMG equipment was attached and MVC measures were performed. Prior to beginning the task, participants were instructed to type with both hands. Participants typed on each device for 5 minutes with a 2 minute rest period in between.

Data Analysis

Mean EMG readings, extracted from the Noraxon's MR-XP Master Edition software for each muscle and each computing device, were normalized using the peak values obtained from the MVC measurements. The peak value used was the single highest point that occurred during the MVC measurement. The first and last five seconds of the data were removed to reduce start up and task completion effects. Data is expressed in terms of percent MVC. A repeated measures ANOVA was used to test for the main effects and interaction effect of computer type, muscle, and side on muscle activation levels. Tukey's HSD tests were used in post-hoc comparisons where appropriate. Analysis was completed using SAS 9.2, and all results were considered significant at an alpha level of 0.1.

RESULTS

In general muscle activation levels were fairly low (Table 2). Repeated measures ANOVA indicated computer type, muscle, side, the side by device interaction (Figure 1) and side by muscle interaction (Figure 2) were significant (Table 3). Tukey results for the muscle, side by device interaction and side by muscle interaction are presented in Table 4. The netbook resulted in significantly higher muscle activation levels than the slate computer and the right side had significantly higher muscle activation levels than the left side. The ECR, EDC and ECU had the highest levels of muscle activation, but were not significantly different from one another. For the side by muscle interaction, the right EDC, right ECR and right ECU had the highest activation of all conditions. They were not significantly different from each other, but they were significantly different from all other combinations. Muscle activation was significantly lower for the left side when using the slate computer than for the other three conditions.

Table 2. Descriptive statistics by task. Values are reported in % of Max

Factor	Level	% of Max (SD)
Computer	Netbook	8.48% (5.79%)
	Slate	7.25% (5.02%)
Side	Left	6.98% (6.98%)
	Right	8.79% (5.81%)
Muscle	BR	5.92% (5.92%)
	ECR	11.34% (5.44%)
	ECU	10.25% (5.02%)
	EDC	10.65% (6.42%)
	FCR	7.40% (4.11%)
	FCU	4.11% (4.49%)
	PL	5.61% (4.55%)

DISCUSSION

The first objective of the study was to determine if the level of muscle activation differed between computing devices. The hypothesis was that there would be lower muscle activation levels for the slate computer than the netbook because of reduced productivity (reduced typing) (Kim, Aulck, Bartha, Harper & Johnson, 2012; Werth & Babski-Reeves, 2012).

Figure 1. Side by Device Interaction. Values are reported in % of Max

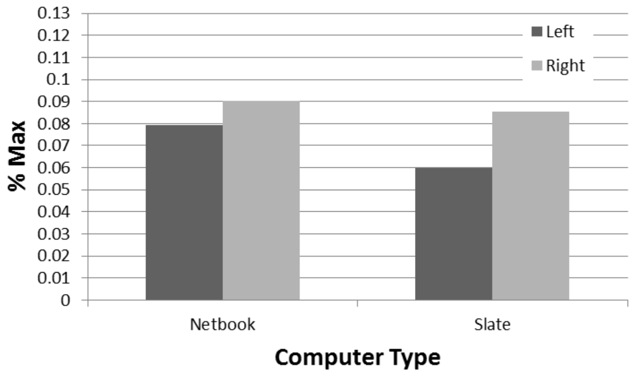

Figure 2. Side by Muscle Interaction. Values are reported in % of Max

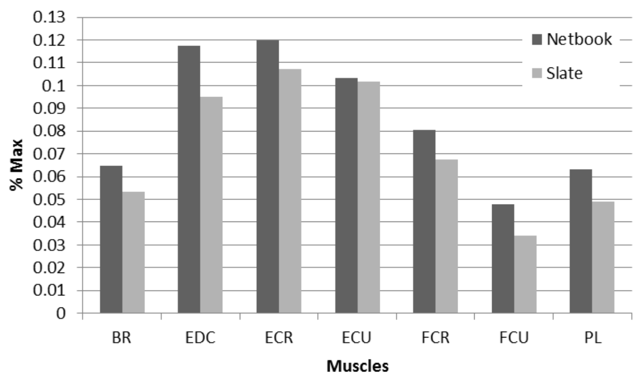

Table 3. ANOVA results. Values are p-values.

Factor	p-values
Computer	**0.0001**
Side	**0.0001**
Muscle	**0.0001**
Muscle x Computer	0.7182
Side x Computer	**0.0117**
Side x Muscle	**0.0001**

Bolded values indicate significant differences

This hypothesis was supported. The slate computer was found to have significantly lower muscle activation levels than the netbook. These findings are similar to those found in previous studies (Werth & Babski-Reeves, 2012). While slate computers do have lower muscle activation levels this does not alleviate the concern that these portable computing devices do pose ergonomic concerns to users. Previous studies have found that for even very low level activations like these can result in low level muscle fatigue (Lin, Liang, Lin & Hwang, 2004) and potentially, WMSD development.

Table 4. Tukey results for muscle activity level

Factor	Level	Mean (% Max)	Grouping
Muscle	ECR	0.1065	A
	EDC	0.1026	A
	ECU	0.1134	A
	FCR	0.0740	B
	BR	0.0592	C
	PL	0.0561	C
	FCU	0.0411	D
Side x Device	Right, Netbook	0.0902	A
	Right, Slate	0.0856	A
	Left, Netbook	0.0795	A
	Left, Slate	0.0600	B
Side x Muscle	Right, EDC	0.1379	A
	Right, ECR	0.1325	A
	Right, ECU	0.1307	A
	Left, ECR	0.0938	B C
	Left, EDC	0.0845	B C
	Left, FCR	0.0845	B C
	Left, ECU	0.0745	B C
	Right, BR	0.0659	B C D E
	Right, FCR	0.0644	B C D E
	Left, PL	0.0574	C D E
	Right, PL	0.0548	C D E
	Left, BR	0.0524	C D E
	Left, FCU	0.0431	E
	Right, FCU	0.0391	E

The second objective of this study was to identify which muscles should be studied when looking at various portable computing devices. The results of this study seem to indicate that both the right and left side muscles are affected differently, but the same muscles are active in both arms and across devices: EDC, ECR and ECU.

One finding in this study that appears to be contradictory to the majority of the previous typing research is that the right side has higher muscle activation levels than the left side. Previous research has demonstrated that the left side is typically more active when using desktop computers (Keir & Wells, 2002). This result is driven by the type of device being used. When comparing the left and right side activation levels on the netbook, there are no differences. However, there are significant differences between the left and right side activation levels for the slate computer. This result is likely due to the fact that two handed typing may not be the natural data entry method when using slate computers because of the virtual keyboard. Therefore, participants may have used their right hand to make edits during the typing process. Also, as previous studies have illustrated that error rates are elevated when using slate computers (Kim, Aulck, Bartha, Harper & Johnson, 2012; Werth & Babski-Reeves, 2012) as the backspace and delete keys are on the right side of the keyboard, elevated activity may be due to the increased use of these keys. Generally, for both the right and left sides, the EDC, ECR and ECU are the most active. However the one difference is for the left side. Along with the three muscles listed, the FCR is also active and resulted in activation levels that were not significantly different than the EDC, ECR and ECU.

In conclusion, there has been a rapid adoption of portable computing devices and the changes to the hardware of these devices may potentially increase the ergonomic risks posed to users, and ultimately increased injury risk. When designing studies to assess the potential ergonomic risk via muscle activation levels, it is important to be aware that the when studying netbooks or portable computing devices with hardware keyboards, it may not necessary to study both the right and left side. However, this research does indicate that the right side of the slate results in significantly higher muscle activation levels than the left side, which is in contrast to prior studies. It will be more important to evaluate both sides in studies involving virtual keyboards.

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