F8-3

The Effects of Smartphone Edge Display on EMG Activity of Thumb Muscles in One-handed Interaction

Min Chul Cha (mc.cha@yonsei.ac.kr)[1] , Hwan Hwangbo (hwan976@yonsei.ac.kr)[1] , Seul Chan Lee (seulchan@yonsei.ac.kr) [1]
Yong Gu Ji (yongguji@yonsei.ac.kr)[1]

[1] Department of Information and Industrial Engineering, Yonsei University, Seoul, Republic of Korea

ABSTRACT

The purpose of this study is to investigate the effect of edge display of smartphone on thumb muscles activity of smartphone users. Sixty-six participants between 20 and 39 years were recruited in the experiment. Participants performed the two tasks which were touch and swipe, which were the most used tasks in smartphone. The independent variable was a smartphone display type (flat display, edge display). The experiment was conducted using a commercially available smartphone. Participants performed the tasks with two size of smartphone while walking or sitting. For checking muscles activity, we attached the surface electromyography (EMG) device to the subjects' hands (especially their thumbs). Two muscles, the first dorsal interosseous (FDI) and the abductor pollicis brevis (APB), were chosen for this study. The results showed that only FDI muscles activity of the edge display smartphone was higher than that of the flat display smartphone, especially in big size smartphone conditions. This excessive muscle activity while using the edge display smartphone can cause musculoskeletal disorders to the user. This study suggests that the smartphone, which is a device that repeats the same thing over and over again, should be designed to decrease user muscle stress.

Keywords: Smartphone, Edge display, Electromyography (EMG), Muscle activity

1. Introduction

Smartphone users are always holding their smartphones with their hands in their daily life. They use their smartphones to play games, do social network system (SNS), browse web, and watch videos for interaction with their family, friends, or other peoples (Do & Gatica-Perez, 2013). Smartphone users' finger muscles suffer from musculoskeletal disorders while using the smartphones, because they touch the smartphone thousands of time (Gustafsson et al, 2017). For this reason, physical comfort is an essential requirement for designing smartphones.

However, Consumers always want that their smartphone has a big display and brand-new design style (Kim, & Sundar, 2014). For this reason, smartphone manufacturers try to produce new smartphones every year and some smartphone have an new design style, such as edge display. Samsung Galaxy S8, recently-announced smartphone, is released in only edge display model. Consumers feel discomfort in their hand muscles when they perform the touch behaviors with the edge display. This discomforts in hand muscles can lead to musculoskeletal disorders (Gerr, Marcus & Monteilh, 2004).

Therefore, the research should be required for investigating the effect of edge display on hand muscles. This study aimed to analyze muscles activity while using edge display smartphones and flat display smartphones in one-hand interaction.

2. Method

2.1. Subjects

Sixty-six participants who were all android smartphone users participated as paid volunteers. Because of a technical issue, only fifty subjects' data were used for analyzing. The subjects consisted of 22 men and 28 women, in their 20s and 30s. The participants were

29.7-year-old on average (SD = 4.18). The prefer hands while using smartphone were almost right hands and just one subject responded said both hands.

2.2. Experiment Design

The aim of this study was to figure out the effect of smartphone edge display to users' finger muscles. The independent variables were width and display type of smartphones.

2.3. Apparatus and Task

Four commercial smartphones (Samsung Galaxy 7, Samsung Galaxy 6 edge, Samsung Galaxy 7 edge, Sony Xperia XZ) were presented for the experiment. Two of them were with flat displays and two were with edge displays. Width of smartphones are 70mm and 72mm (Table 1).

Display / Width	Flat	Edge
70mm	Samsung Galaxy 7	Samsung Galaxy 6 edge
72mm	Sony Xperia XZ (2016 model)	Samsung Galaxy 7 edge

Table 1. Commercial smartphone list used in experiments

Shimmer 3 EMG device that had two muscle channels was used for measuring subjects muscle activity. Surface electrodes were attached to subject's finger muscles. Electromyography (EMG) signals were collected with 512Hz data sampling rate and a bandpass filter was adapted between 20 and 250 Hz.

A smartphone tapping task (Figure 1) was performed. The researchers developed an experimental application, which was used for the task. The target dots were randomly presented on the screen. Participants were asked to tap 100 times each smartphone while sitting or walking situation.

2.4. Finger muscles

EMG data were measured on the first dorsal interossei (FDI) and abductor pollicis brevis (APB) of right thumb. Two muscles were mainly activated during abduction activities of the thumb. FDI is on the adjacent surfaces of the thumb and index and APB is on the palm between the thumb and wrist. It is generally known that two muscles are used for using smartphone (Kwon et al, 2016; Chang et al, 2017).

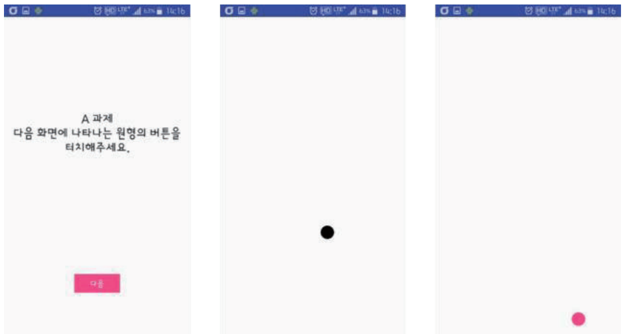

Figure 1. Example of tapping task screen

2.5. Experimental Procedure

Before the experiment started, researchers explained the purpose of experiment and procedure. Then participants fill out the demographic survey form. Simultaneously, researchers measured the right-hand size (thumb length and hand length) and attached the surface electrode on subject's hand. After the preparatory stage, reference voluntary contraction (RVC) of each muscle was measured. Next, the subject was asked to perform the tapping task while sitting on the table and walking on the treadmill.

2.6. Analysis

EMG data were normalized to RVC. Data between 20s and 40s of task time was used for analyzing the results, and root mean square (RMS) was calculated by using Matlab program. The window size for computing the features was 100.

It seemed possible that there was not only the effect of different smartphones, but there were also the effects of other factors such as task condition, gender, hand size, and thumb length. To determine the effects of those factors on muscle, the multi-way analysis of variance (multi-way ANOVA) test conducted.

3. Results

3.1 FDI Muscle Activity

According to the result of ANOVA, the main effects of smartphone devices, task condition, gender, national, hand size, and thumb size were confirmed. But there were no significant differences by the interaction effects.

The effects of edge display on FDI muscle were significant ($p < 0.05$). The highest EMG signal recorded when subjects were using a 72mm edge smartphone (M =

44.2%, SD = 28.03%), followed by 72mm flat (M = 38.7% SD = 23.90%), 70mm flat (M = 37.1%, SD = 21.62%) and 70mm edge (M = 36.0%, SD = 21.41%) (Figure 2). These results showed that the effect of edge display on the FDI muscle was increased in the large smartphone size.

There was significant effect of task condition ($p < 0.05$). FDI muscle activity was 5% more in walking situation (M = 40.6%, SD = 23.88%) than in sitting situation (M = 36.4%, SD = 22.57%) (Figure 3).

The effects of gender on FDI muscle activity were found ($p < 0.05$). Female (M = 40.8%, SD = 23.42%) used FDI muscle more than male (M = 35.6%, SD = 22.83%) (Figure 4).

To compare the effect of hand and thumb size, the researchers divided the hand and the thumb size into three groups (small, medium, large). The significant differences were found in hand and thumb size ($p < 0.05$). The large hand size group used less FDI muscle than the small hand size group (small: M = 44.2%, SD = 23.00%; medium: M = 39.8% SD = 22.09%; large: M = 29.4%, SD = 22.40%) (Figure 5). However, the medium thumb size subject used the FDI muscle with minimum effort (small: M = 43.6%, SD = 24.34%; medium: M = 33.5% SD = 21.30%; large: M = 37.26%, SD = 21.30%) (Figure 6).

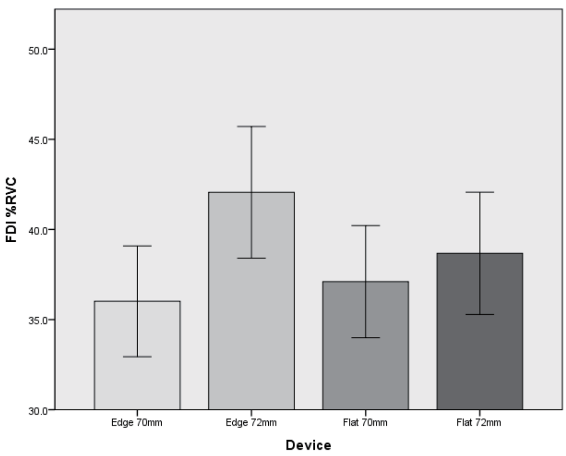

Figure 2. The %RVC of FDI muscle according to smartphone types

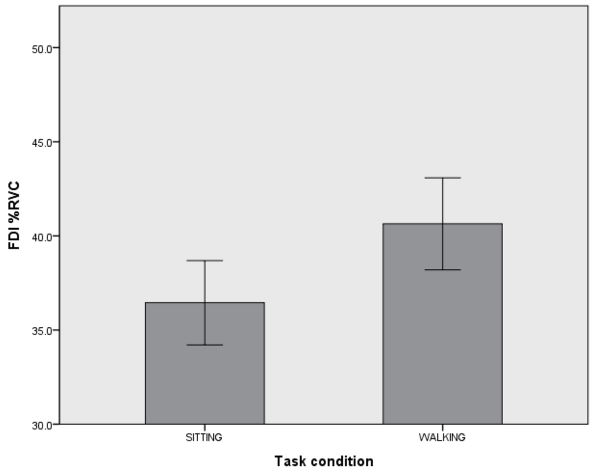

Figure 3. The %RVC of FDI muscle according to task condition

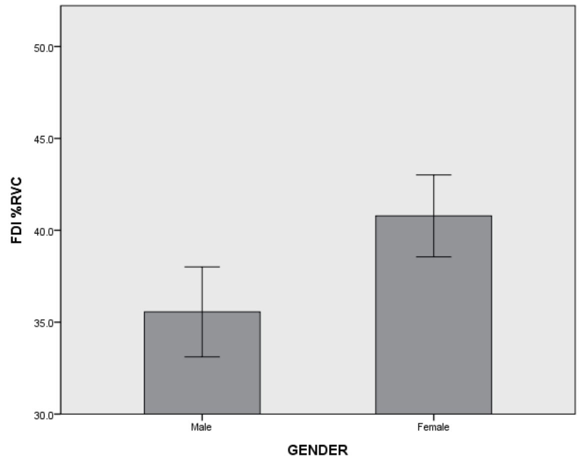

Figure 4. The %RVC of FDI muscle according to gender

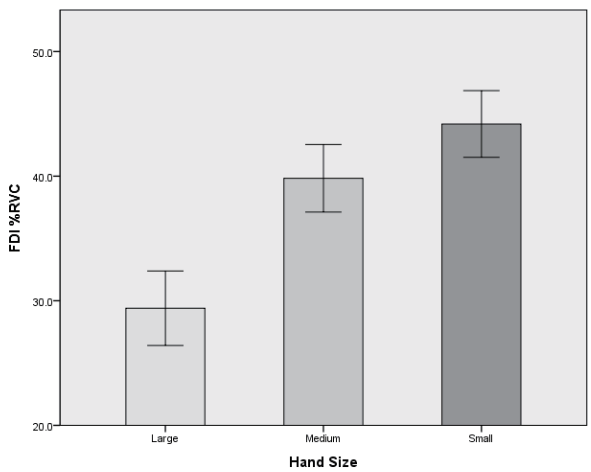

Figure 5. The %RVC of FDI muscle according to hand size

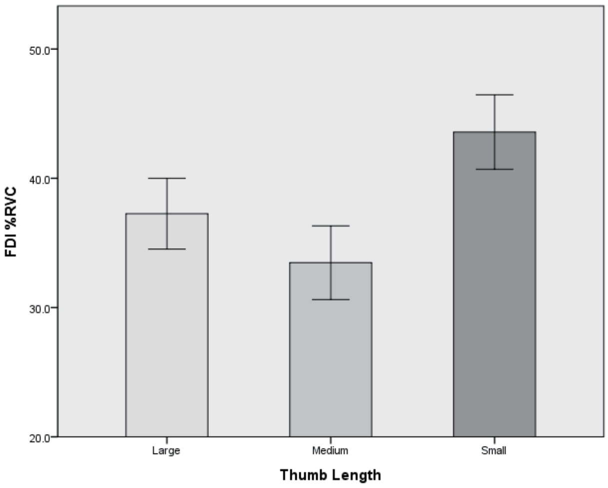

Figure 6. The %RVC of FDI muscle according to thumb length

3.2 APB Muscle Activity

In contrast to previous researches and the result of FDI muscle, there were no significant effect of variables in APB muscle activity. Not only main effects, but also interaction effects did not significantly affect to APB muscle signal.

4. Conclusion

In this study, the FDI muscle activity was affected by the smartphone edge display. There was no difference in APB muscle. The overstrained muscles can be a trigger for a musculoskeletal disorder while using smartphone. Although this experiment was conducted about two size of smartphone width, the edge display might be fine to be applied to the smartphone for an attractive design or an additional function. Whereas it should be avoided to equip the edge display in large smartphone (over 72mm), like Samsung S7 edge, note 7 edge, and S8+ models

The effects of edge display to older adults were larger than those of edge display to younger adults. Previous studies revealed that the old adults have difficulties using smartphone and high probability of musculoskeletal disorder. Therefore, a further research to be aim at old adults should be conducted. And because there are some limitations in experiment, only two muscles were measured. It is required to study the effect of the edge display on the different hand muscles.

Acknowledgements

This work is financially supported by Korea Ministry of Land, Infrastructure and Transport(MOLIT) as 「U-City Master and Doctor Course Grant Program.

References

Do, T. M. T., & Gatica-Perez, D. (2013). Human interaction discovery in smartphone proximity networks. Personal and Ubiquitous Computing, 17(3), 413-431.

Gustafsson, E., Thomée, S., Grimby-Ekman, A., & Hagberg, M. (2017). Texting on mobile phones and musculoskeletal disorders in young adults: A five-year cohort study. Applied Ergonomics, 58, 208-214.

Kim, K. J., & Sundar, S. S. (2014). Does screen size matter for smartphones? Utilitarian and hedonic effects of screen size on smartphone adoption. Cyberpsychology, Behavior, and Social Networking, 17(7), 466-473.

Gerr, F., Marcus, M., & Monteilh, C. (2004). Epidemiology of musculoskeletal disorders among computer users: lesson learned from the role of posture and keyboard use. Journal of Electromyography and Kinesiology, 14(1), 25-31.

Kwon, S., Bahn, S., Ahn, S. H., Lee, Y., & Yun, M. H. (2016). A study on the relationships among hand muscles and form factors of large-screen curved mobile devices. International Journal of Industrial Ergonomics, 56, 17-24.

Chang, J., Choi, B., Tjolleng, A., & Jung, K. (2017). Effects of button position on a soft keyboard: Muscle activity, touch time, and discomfort in two-thumb text entry. Applied Ergonomics, 60, 282-292.