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Are Lighter Smartphones Ergonomically Better?

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Objective: The aim of this study was to understand the effects of phone weight on the typing performance and muscle recruitment in the neck and upper extremity while typing a text message with dominant hand. The iPhone4 and iPhone5 were compared due to their 28-gram differences in weight.

Background: Too much use of a cellular phone can lead the musculoskeletal disorders in the upper extremity. Phone makers tend to make their new models bigger, lighter, faster and smarter.

Method: Fourteen healthy volunteers without any history of neuromuscular disorders or ongoing pain who used their smartphone more than one year were recruited. A 112g phone (iPhone5) and a 142g phone (iPhone4) were used for typing the lyric of the Korean national anthem with their dominant hand. Typing duration, the typing error, the perceived fatigue, and preference was investigated. Muscle recruitment and the resting gap of neck (middle trapezius and levator scapula), shoulder (infraspinatus and mid deltoid), elbow (biceps brachii and brachioradialis), thumb (extensor and abductor policis brevis) were collected using surface electromyography. Typing error was counted and typing speed was calculated in characters per min. The data were analyzed using a paired t-test and chi-square (χ^2) analysis for the effects of phone weight on the typing performance parameters and muscle recruitment.

Results: Typing text message with iPhone5 took longer but had less muscle recruitment in brachioradialis, and extensor policis brevis muscles. Lighter weight of iPhone5 made biceps brachii to rest less without increasing the mean %EMG.

Conclusion/Application: Findings of this study can be valuable information for phone designers to develop more productive device and for smartphone users to prevent the musculoskeletal disorders in the upper extremities.

Keywords: Smart phone, Electromyography, Perceived fatigue, Upper extremity, Typing

1. Introduction

Smartphone are increasingly popular not only for phone calls but also for internet, text messaging, applications and games (Adeoye and Tomei, 2014). Smartphone users frequently replace their functionally intact phones (Yap, 2013) for newest design and the up-to-dated technology. The frequent replacement has resulted in tremendous sales of smartphone (more than half of all mobile phone) worldwide (Wikipedia, 2013). Smartphone market is the hottest battle field of electronic industry.

Smartphone users type text messages throughout the day with its small keypad.

Too much use of smartphone can cause prolonged awkward posture of the neck and high repetitive movement of the hand (Holmes, 2013). In a retrospective study (Sharan and Ajeesh, 2012), most common problems were in the thumb extensors and intrinsic muscles. Sustained and prolonged gripping and repetitive movements have all been identified as risk factors which may lead to disorders of the upper extremities (Fredriksson, 1995, Moore, 1997, Barr et al., 2004).

Phone makers tend to make their new models bigger, lighter, faster and (doubtfully) smarter. For an example, Apple (Apple, 2013) underscored that their new phone is lighter than ever with bold characters in their internet advertisement. It was 28 grams lighter than their previous model. It seems a significant improvement in technology. However, is it ergonomically better?

There is a gap in quantifying and/or comparing the biomechanical characteristics of different smartphones. Features of smartphones, such as their width, height, depth, weight, surface material, can affect the biomechanical load and the performance of its users. It is meaningful to evaluate whether a small change in the feature of a smartphone can really affect its uses biomechanically and functionally. The aim of this study was to investigate the effects of 28-gram difference in phone weight on the typing performance and the muscle recruitment in the neck and upper extremity while typing with one hand.

2. Method

2.1 Subject

Fourteen (7 females and 7 males) young voluntary subject without any pain during the past month or any history of neuromuscular disorders in the neck and upper extremities were recruited (Table 1). They have used their own smartphones more than a year. Two were iPhone4 users and none had iPhone5. All subjects were read and signed the Yonsei University Wonju Institutional Review Board approved consent form.

Table 1. General characteristics

Variables	Male (n=7)	Female (n=7)	Total (n=14)
Age (years)	21.14±1.95	22.00±1.15	21.57±1.60
Height (cm)	177.57±5.53	161.00±6.32	169.29±10.32
Weight (kg)	74.71±11.44	54.14±5.81	64.43±13.78
BMI (kg/m^2)	23.80±4.18	20.90±1.77	22.35±3.43
Using time per a day (hour)	5.86±3.34	6.86±3.72	6.36±3.43
Text messages daily (hour)	4.00±2.71	3.43±2.51	3.71±2.52

2.2 Instruments

The iPhone4 and iPhone5 (Apple Inc, Cupertino, CA, USA) were selected for data collection in this study because their width was identical with same keypad. An iPhone4 is 140g and its dimension is 115.2*58.6*9.3mm (height*width*depth) and an iPhone5 is 112g and its dimension is 123.8*58.6*7.6mm (Apple, 2013). A small difference in height and depth does not change the keypad size. The major difference between iPhone4 and iPhone5 was in their weight, 28 grams.

The electromyography was used for collecting the muscle recruitment data of right eight superficial muscles with using the

Tele-Myo 2400T EMG instrument with a wireless telemetry system (Noraxon, Scottsdale, AZ, USA). Before the electrode placement to diminish skin resistance, the skin of subject was shaved, sanded, and swabbed with alcoholic wipe. Disposable Ag/AgCl surface electrodes were located parallel to the muscle fibers with a 2cm center-to-center spacing. Myo-Research Master Edition 1.06 XP software (Noraxon) was used to inspect and analyze the data. The raw signal at the sampling rate of 1,000Hz was filtered using a digital band-pass filter between 20 and 400Hz to remove movement artifacts, and a 60-Hz notch filter was applied to diminish electrical noise. Surface EMG electrodes were placed on the right levator scapula (LS), middle trapezius (MT), infraspinatus (IS), middeltoid (MD), biceps brachii (BB), brachioradialis (BR), extensor pollicis brevis (EPB), abductor pollicis brevis (APB) as recommended by previous studies (Cram and Kasman 1998; Perotto and Delagi 2005).

2.3 Testing procedure

Subjects were seated in an erect posture (adducted shoulder girdles) on a chair with backrest but no armrest. The subjects were instructed as hips and knees were flexed at 90° and elbows flexed at 90° with internal rotation of shoulder naturally for typing with smartphone (Kim, et al., 2012). Either iPhone4 or iPhone5 without a case was randomly given right before a trial. Sufficient (at least 5 minutes) typing practice period was provided prior to data collection. Subjects were asked to type the lyric of the Korean national anthem (79 characters with space) with their dominant hand as fast as possible. There were at least 1-minute breaks between trials. The phone was vertically oriented and located in 10-cm front of the xiphoid process of sternum. The upper arm was kept in contact to the side of trunk and the wrist was maintained in neutral position. Subjects were reminded to stop at any time when there is unbearable discomfort.

2.4 Data processing

Typing duration was measured from the beginning ("ready, set, and go!" by tester) to the end ("done!" by subject) of each task. Number of mistyping was counted by a single person after the typed message was sent. At the end of each task, the subjects were asked to rate their perceived fatigue (0: no discomfort to 10: most discomfort). Ratings of perceived discomfort have been reported to be more reliable than ratings of fatigue based on electromyographic measurements (Sood et al., 2007). At the end of all trials, subjects were asked to choose their preference between two phones.

The EMG data were collected continuously throughout each typing trials. Middle 30-second data were processed after visual inspection for unusual signal. The mean %EMG was calculated during the middle 30-second data. For normalization, the root-mean-square (a moving window of 50ms) of a 5-s maximal voluntary isometric contraction (MVIC) was calculated three times on each muscle to provide a base for EMG signal amplitude normalization. The manual muscle testing positions for the MVIC were practiced as recommended by previous study (Kendall, et al., 2005). We used center 3s of collected data to decide the mean amplitude of MVIC. Resting gap in EMG data was defined the proportion of typing duration when the %EMG was less than half of the mean %EMG.

2.5 Data analysis

Paired *t*-test was used to test the effect of phone weight on the typing duration, the typing error, the perceived fatigue, the mean %EMG, and the resting gap. Chi-square (χ^2) analysis was used for preference. Level of significance was set at .05. SPSS version 13 was used for statistical analysis.

3. Results

3.1 Typing duration, error, fatigue and preference

The iPhone5 took 24 seconds (±18.3) longer to complete the typing task (p<.01). The typing duration was 123.4±27.1 seconds with iPhone4 and 147.4±30.9 seconds with iPhone5 (Figure 1). There was no statically significant difference in the typing error (p=.39) or in the perceived fatigue (p=.17) between phones. Preference was tied in 7:7 (p=.90).

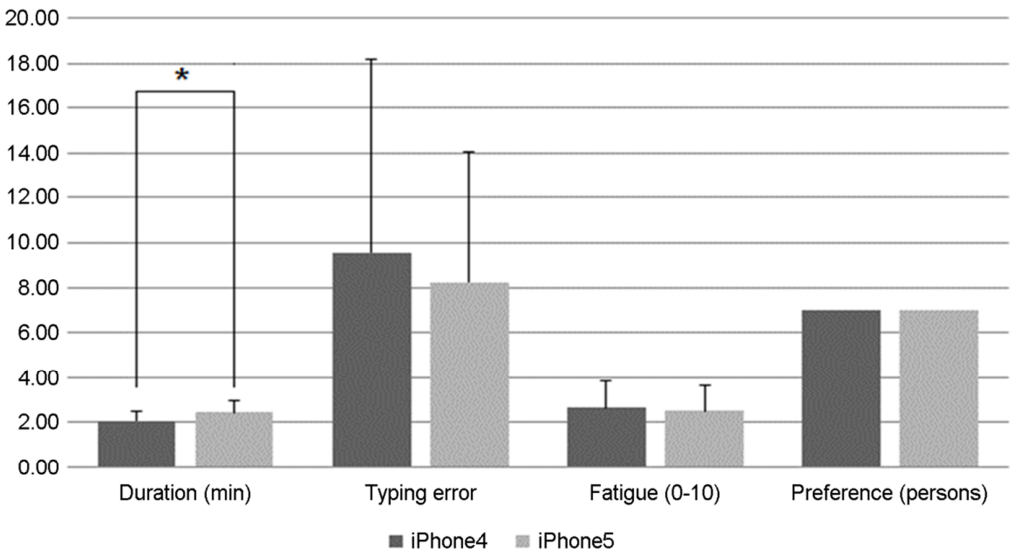

Figure 1. Typing duration, error, fatigue and preference between iPhone4 and iPhone5 (asterisks mean statistical significance between two phones)

3.2 EMG

The relative levels of muscle recruitment were less than 20% of the maximal voluntary contractions (Figure 2). Neck and thumb muscles were main contributors for typing. The typing with the iPhone5 had lesser mean %EMG of BR and EPB (p=0.01 and p<0.01). No statistically significant difference was observed in all other muscles.

The resting gap was less than 5% of typing duration for most of muscles observed in this study (Figure 3). EPB rested about 20% and APB was about half working and half resting. The only significant difference was in BB (p=0.02).

4. Discussion

4.1 Typing duration, error, fatigue and preference

Typing with iPhone5 took longer in 13 of 14 subjects. Only two were iPhone4 users and none had iPhone5 at the time of data collection. Although iPhone5 was new to subjects, the dimension of iPhone5 keypad was identical to that of iPhone4. It is more reasonable to explain that the prolonged typing duration with iPhone5 is due to its lighter weight.

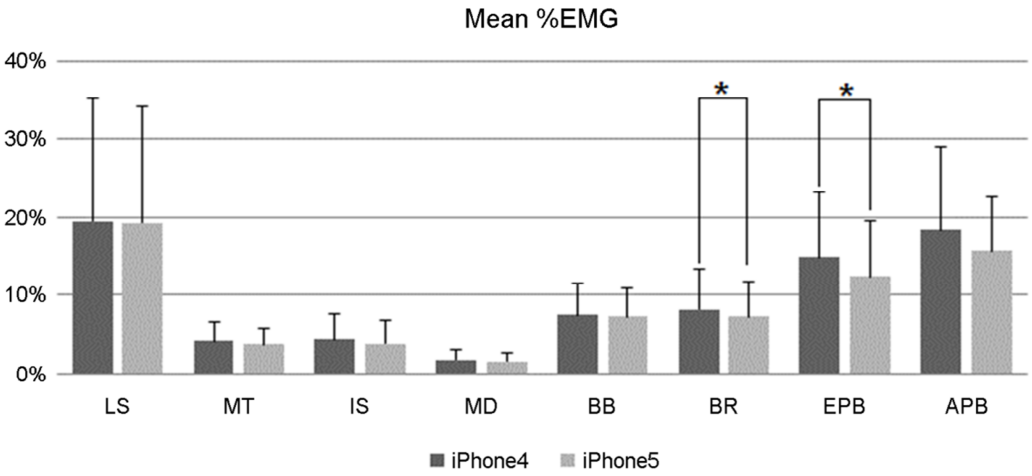

Figure 2. Mean %EMG of levator scapula (LS), middle trapezius (MT), infraspinatus (IS), middeltoid (MD), biceps brachii (BB), brachioradialis (BR), extensor pollicis brevis (EPB), abductor pollicis brevis (APB) muscles while typing with iPhone4 and iPhone5 (asterisks mean statistical significance between two phones)

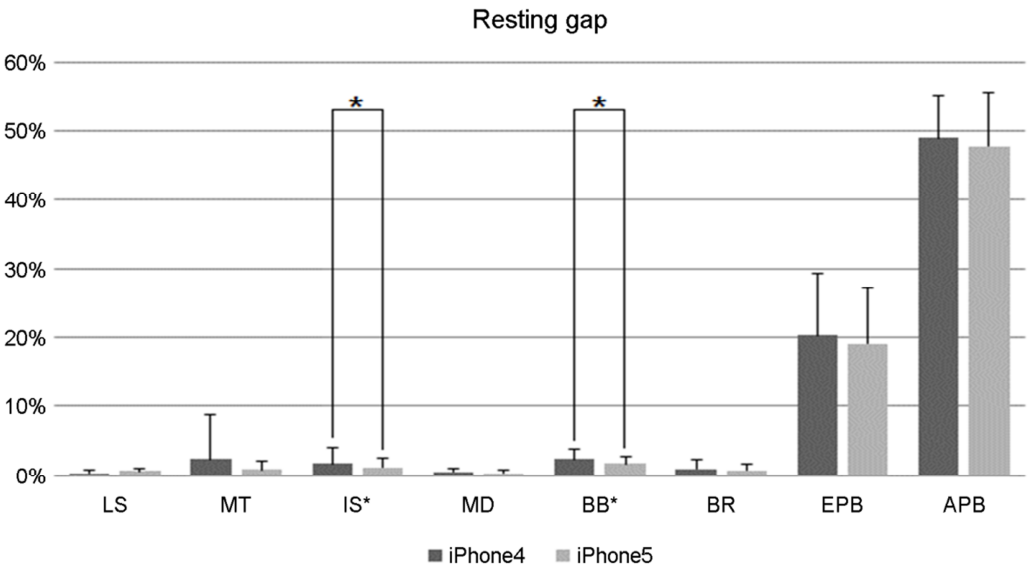

Figure 3. Resting gap (the proportion of typing duration when the data were less than half of the mean %EMG) of levator scapula (LS), middle trapezius (MT), infraspinatus (IS), middeltoid (MD), biceps brachii (BB), brachioradialis (BR), extensor pollicis brevis (EPB), abductor pollicis brevis (APB) muscles while typing with iPhone4 and iPhone5 (asterisks mean statistical significance between two phones)

Typing on a smartphone with one hand is a dual task: holding the phone in the space with the fingers and hitting the key with the thumb. In dual tasks (Ruiz Fernandez et al., 2011), increased level of difficulty of one task found to delay the other task duration implicitly. In Newton's physics (F = ma), an object with lighter weight could be more perturbed when forces applied. The motion of thumb can affect more the lighter phone than the heavier one. Increased perturbation requires more effort in stabilizing the phone at specific location and it can delay the duration of hitting the keypad as If the phone is too heavy, on

the other hand, it will be more stable but there need to be more mechanical demand to hold it in the space. There might be an optimal weight of Smartphone balancing the demands to hold it and type on it.

Typing error was not affected by lighter weight of phone since the dimensions of the two keypads were same. Perceived fatigue and subjective preference (surprisingly, it was 7:7) did not reflect the lighter weight or other features of iPhone5. Subjects felt iPhone5 cognitively felt lighter, but the difference in weight may not be sufficient to alter the perceived fatigue or subjective preference. Nevertheless, subjects knew that it takes longer to type with the iPhone5 when they answered their perceived fatigue and preference.

4.2 EMG

Typing with one hand require stabilizing the proximal joints while moving the thumb at the same time. Direct benefit of lighter phone was less demand on muscle recruitment to hold the phone against gravity. It was the decreased mean %EMG on BR, which maintains the elbow joint in flexion while typing on the phone. In addition, there was an indirect benefit of lighter phone, the decreased muscle recruitment of thumb (EPB). Control of these functions seems not to be independent. Lighter weight seemed to affect both functions. When more than two muscle groups are activated simultaneously for their own purposes, the exertion level of one muscle group affects the other group in a grip study (Seo, 2009). Similar findings were in individual fingers during multiple finger prehension (Kinoshita et al., 1995), and even in bilateral exertion of lower extremities (Vandervoort et al., 1984).

Resting gap of muscles, except thumb muscles, was very low while typing on the smartphone with one hand but their mean %EMG was lower than 20%. It means these muscles maintained certain level of contraction statically even their activity level was not high. Lighter weight of iPhone5 made BB to rest less without increasing the mean %EMG in this study. It can be explained by more perturbation at the elbow joint while typing the lighter phone. In the thumb muscles it was opposite; they were doing a dynamic task, cycling between contraction and relaxation.

Limitation of this study was, firstly, the samples size was small. That could explain why failing to show the statistical significance in some muscles. Secondly, typing took 2 to 3 minutes for most of subjects and it seems to be far less than what the people do in real life. Thirdly, all subjects were young and experienced users.

Phone makers will keep trying to make their phone lighter and lighter. This study suggests that there can be an optimal weight of smartphone for typing with one hand. If it is too heavy, it will demand more elbow and thumb muscles. If too light, typing will take longer. There should be a thin line between these two. Further researches are needed in quantifying the biomechanical consequence of changing features of smartphones.

5. Conclusion

The purpose of this study was to compare the performance of typing with iPhone4 and iPhone5. Typing text message with lighter iPhone5 took longer but had less muscle recruitment in brachioradialis, and extensor policis brevis muscles. Lighter weight of iPhone5 made BB to rest less without increasing the mean %EMG. Findings of this study can be valuable information for phone designers to develop more productive device and for smartphone users to prevent the musculoskeletal disorders in the upper extremities.

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