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Analysis of the effect of overusing thumbs on smartphone games

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Abstract

Objective: To assess the impact of repetitive movements of the thumb caused by playing a smartphone game continuously for 30 min.

Methods: This study recruited healthy volunteers. They were instructed to play a game called Subway Surfers, which ran continuously. Subjects played the game for 30 min. The function of the abductor pollicis brevis and extensor pollicis brevis muscles was assessed by surface electromyography and the signals were obtained at 10 min, 20 min and 30 min. The median frequency (MDF) was used as an indicator of muscle fatigue. A visual analogue scale (VAS) was used to assess the subjective discomfort of the volunteers.

Results: Twelve subjects participated in this study. The MDF of the abductor pollicis brevis and extensor pollicis brevis muscles decreased significantly over the test period. The MDF of the extensor pollicis brevis had decreased significantly by 10 min after the start of the gaming session, while the abductor pollicis brevis had decreased significantly by 20 min. The VAS scores significantly increased after 30 min of continuous gaming.

Conclusions: This study suggests that playing continuous games on a smartphone might result in chronic muscle injury. Continuous gaming time should be kept below 20 minutes.

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Keywords

Smartphone, muscle fatigue, visual analogue scale, median frequency

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Introduction

Smartphones are widely used and have become an integral part of everyday life. With the decline in price, mobile phones have become more readily accessible. By the end of 2016, the number of mobile phone users in China had reached 1.28 billion.[1] The variety of applications available on smartphones makes communication between people convenient and a regular part of people's daily lives. The mobile gaming industry is thriving and there are a variety of different types of games available to owners of smartphones. The portability of mobile devices eliminates the space limitations of fixed-line gaming platforms, allows for short breaks in entertainment, and makes mobile social gaming a popular choice for leisure activities.[2] The ready availability of mobile games means that the usage time of mobile phones may have become longer than in the past when these games were not available. On one hand, playing games can be used to train or learn new knowledge, especially in adolescents. In contrast, addiction to smartphone games can also bring many individual and social problems. The most common problems are game addiction and coercion. These can lead to long play times and mental health issues, such as depression, loss of self-esteem and social anxiety.[3]

People are spending more leisure time on smartphones. According to reports, more than 80% of students use smartphones for 5–6 hours a day, while the most active users are almost constantly interacting with their devices.[4,5] Smartphone games play an important role in maintaining addictive smartphone behavior.[6] In response, young people identified leisure as their primary purpose of using a mobile phone.[7] Playing games on their smartphones is an important part of how young people spend their leisure time, which creates many psychological and physical problems.[8]

A large number of studies have explored the impact of the use of mobile phones, but these have mainly focused on the impact on identity rather than physical discomfort.[9–13] While some researchers have concerns about the impact of mobile phone use on driver distraction whilst driving vehicles.[14,15] Research has also explored the association between mobile phone use and behaviour and sleep quality.[16]

Most smartphones are manipulated by touching the screen and the operation largely depends on the movement of the thumbs. The overuse of the thumb leads to many physical discomforts and may cause muscle and tendon problems.[17] Research has suggested that musculoskeletal discomfort is closely related to the duration of smartphone use, but the research focused on the neck and shoulder muscles.[18] The traditional way to play computer games is to use a handle or a computer keyboard, but most smartphones are manipulated by touching the screen. The games used in this current study depended heavily on the ability to quickly and repeatedly touch the screen and relied on the movement of the thumbs. Therefore, thumb movements that involve the extensor pollicis brevis and abductor pollicis brevis means that these muscles can be easily overused. It is necessary to evaluate the function of both muscles. This current study explored the relationship between playing continuous smartphone games and fatigue of the muscles around the thumb. The current study hypothesized that extended smartphone game playing would result in muscle fatigue and muscle discomfort.

Subjects and methods

Study subjects

This study recruited healthy volunteers from Shanghai Jiao Tong University, Shanghai, China. The study was conducted at the Gait Laboratory of the Engineering Research Centre of Digital Medicine and Clinical Translation, Ministry of Education of P.R. China, Shanghai, China between May 2018 and August 2018. The inclusion criteria were as follows: (i) each subject had owned their smartphone for $\geq$12 months; (ii) right hand-dominant; (iii) familiar with the game. The exclusion criteria were as follows: (i) wrist pain; (ii) congenital malformations; (iii) severe neurological disease, upper limb injury or upper limb pain for the previous 6 months. Demographic data including age and sex were recorded for all study participants.

The experimental protocol was approved by the Ethics Committee of the Ninth People's Hospital of Shanghai affiliated to Shanghai Jiao Tong University, School of Medicine, Shanghai, China (no. 2017/33). All subjects provided written informed consent in accordance with the tenets of the Declaration of Helsinki before participating in the study.

Study procedures

Each subject used their own smartphone for this study. A Trigno$^{\text{TM}}$ Wireless EMG system (Delsys Inc., Boston, MA, USA) was used to collect the surface electromyography (sEMG) signals from the abductor pollicis brevis and extensor pollicis brevis muscles, which are associated with touching the phone screen. The main function of the abductor muscle of the thumb is to abduct the thumb and the main function of the extensor muscle of the thumb is to stretch the thumb (Figure 1). The sampling rate was set to 2000 Hz, and the bandwidth for EMG signal noise suppression was set to 20–450 Hz. The subjects were instructed to keep playing the game for 30 min. The subjects were instructed to play a game called Subway Surfers (Kiloo Games, Aarhus C, Denmark), which ran continuously.

Subjects sat comfortably in an adjustable chair with their feet on the floor and their elbows on the table. The right thumb was used to control the phone by touching the screen. The angle between the right forearm and the table plane was 30° (Figure 2). All subjects were allowed to touch the screen with their right hands during the tests. Each test lasted at least 30 min. Before the evaluation, the subjects avoided overusing their forearms and hands for at least 24 h. The locations of the electrodes were proximal of the thenar and dorsal side of the distal forearm. The electrodes were parallel with the muscle fibres. Before the electrodes were attached to the skin of the subjects, the hair was shaved from the skin surface and the skin cleaned with alcohol.

Measuring the sEMG signal

The sEMG signals were acquired during the test at the following time-points: before the test began (0 min); every 10 min; and when the test terminated (30 min). The data from each muscle were interpreted by Fast Fourier Transform and spectral analysis and the median frequency (MDF) and mean power frequency (MPF) were used as an indicator of muscle fatigue. When muscles become fatigued, the spectrum moves downwards.[19]

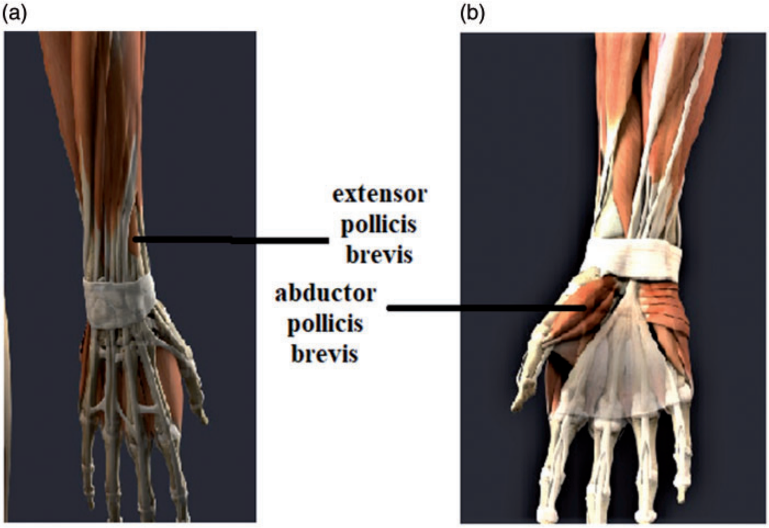

Figure 1. The main function of the abductor and extensor muscles is to abduct the thumb and stretch the thumb, respectively.

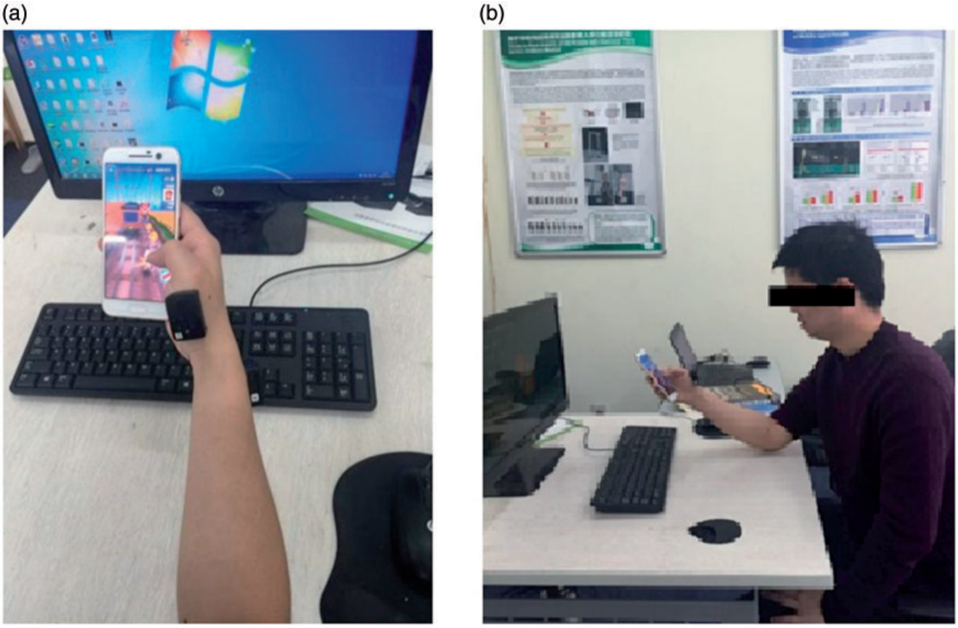

Figure 2. The position of the volunteer during smartphone game playing. (a) The thumb was tested while volunteers played games on their mobile games. (b) The physical position of volunteers participating in the study.

Visual analogue scale (VAS) scores[20] were recorded every 10 min during the test on a scale ranging from 0 (no discomfort) to 10 (unbearable discomfort).

The formula for calculation of MDF is as follows:

$$\mathrm{X(f)} = fft(x(t))$$

$$\sum_{1}^{MDF} |X(f_i)| = \sum_{MDF}^{M} |X(f_i)|$$

Where $x(t)$ is sEMG signals, X(f) is discrete fourier transform of sEMG signals, $|X(f_i)|$ is the ith line of spectrum, f_i is the frequency variable, M is the highest harmonic considered (in this study, M means Nyquist Frequency, half of the sample frequency).

The formula for calculation of MPF is as follows:

$$\mathrm{Power}(f_i) = |X(f_i)|^2$$

$$\mathrm{MPF} = \frac{\sum_{1}^{M} Power(f_i) * f_i}{\sum_{1}^{M} Power(f_i)}$$

Where $Power(f_i)$ is the ith line of power spectrum, f_i is the frequency variable, M is the highest harmonic considered(in this paper, M means Nyquist Frequency, half of the sample frequency).

Statistical analyses

All statistical analyses were performed using the SPSS® statistical package, version 13.0 (SPSS Inc., Chicago, IL, USA) for Windows®. Data are presented as mean ± SD. After establishing if the data were normally distributed and had equivalent variance, one-way analysis of variance was used to identify any significant differences in the changes in parameters over the various time-points during the test period. *Post-hoc* analysis was performed to assess the differences between different time-points. A P-value < 0.05 were considered statistically significant.

Results

This study recruited 12 healthy volunteers: seven females (58%) and five males (42%) with a mean ± SD age of 24.2 ± 2.2 years (range, 21–28 years).

The MDF of the abductor pollicis brevis and extensor pollicis brevis muscles over the test period are shown in Figure 3. The MDF of the two muscles gradually reduced over the test period. For the abductor pollicis brevis muscle, there was a significant difference between baseline mean ± SD MDF (0 min; 8.790 ± 1.981), 10 min (7.965 ± 1.813), 20 min (6.403 ± 1.362) and 30 min (6.019 ± 1.661) ($P < 0.05$). The *post-hoc* analysis found that the mean ± SD MDF was significantly decreased at 20 min compared with baseline (0 min) ($P = 0.008$). Similarly, the mean ± SD MDF was significantly decreased at 30 min compared with baseline (0 min) ($P = 0.013$). However, no significant difference was found between the mean ± SD MDF at 10 min and 20 min. For the extensor pollicis brevis muscle, there was a significant difference between baseline mean ± SD MDF (0 min; 5.073 ± 0.500), 10 min (4.554 ± 0.389), 20 min (4.370 ± 0.395) and 30 min (4.245 ± 0.397) ($P < 0.05$). The *post-hoc* analysis found that the mean ± SD MDF was significantly decreased at 10 min, 20 min and 30 min when compared with baseline (0 min) ($P = 0.017$, $P = 0.023$ $P = 0.012$, respectively). However, no significant difference was found between the mean ± SD MDF at 10 min and 20 min.

The mean ± SD VAS scores for discomfort during the tests are presented in Figure 4. Analysis of variance showed that there were significant differences among

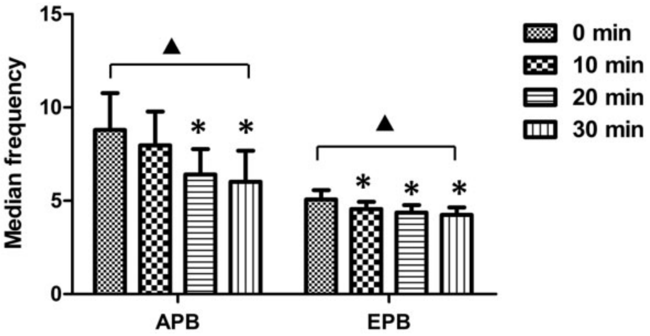

Figure 3. Median frequency of the abductor pollicis brevis (APB) and extensor pollicis brevis (EPB) muscles over the test period. One-way analysis of variance was used to compare the median frequency of the APB and EPB between 0 min, 10 min, 20 min and 30 min. Data are expressed as mean ± SD. ▲$P < 0.05$ among 0 min, 10 min, 20 min and 30 min. *$P < 0.05$ versus 0 min (*post-hoc* analysis).

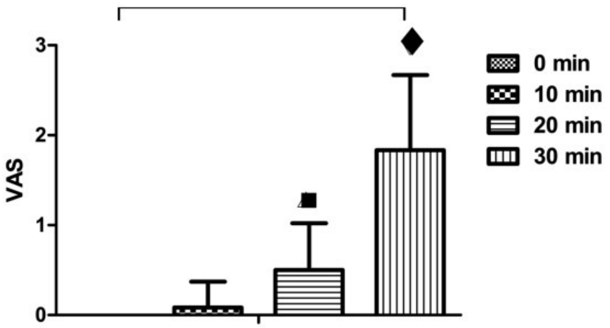

Figure 4. Visual analogue scale (VAS) scores over the test period. One-way analysis of variance was used to compare the VAS scores between 0 min, 10 min, 20 min and 30 min. Data are expressed as mean ± SD. ▲$P < 0.05$ among 0 min, 10 min, 20 min and 30 min. ■$P < 0.05$ versus 10 min. ◆$P < 0.05$ versus 20 min.

baseline mean ± SD VAS scores (0 min) (0), 10 min (0.083 ± 0.289), 20 min (0.500 ± 0.522) and 30 min (1.883 ± 0.835) ($P < 0.05$ for all comparisons). The *post-hoc* analysis showed that the mean ± SD VAS score was significantly higher at 20 min compared with 10 min ($P < 0.05$) and at 30 min compared with 20 min ($P < 0.05$).

Figure 5 presents the MPF results for the abductor pollicis brevis and extensor pollicis brevis muscles during the test period. For the abductor pollicis brevis muscle, the mean ± SD MPF significantly decreased from baseline (0 min) (46.332 ± 3.181) to 10 min (38.568 ± 3.697), then to 20 min (35.846 ± 3.265) and to 30 min (33.472 ± 4.103) ($P < 0.05$). The *post-hoc* analysis showed that the mean ± SD MPF was significantly decreased at 10 min, 20 min and 30 min when compared with baseline (0 min) ($P < 0.05$ for all comparisons). There was no significant difference between 10 min, 20 min and 30 min. For the extensor pollicis brevis muscle, the mean ± SD MPF significantly decreased from baseline (0 min) (27.913 ± 2.241), to 10 min (24.725 ± 1.966), then to 20 min (22.260 ± 2.380) and then to 30 min (18.75 ± 2.058)

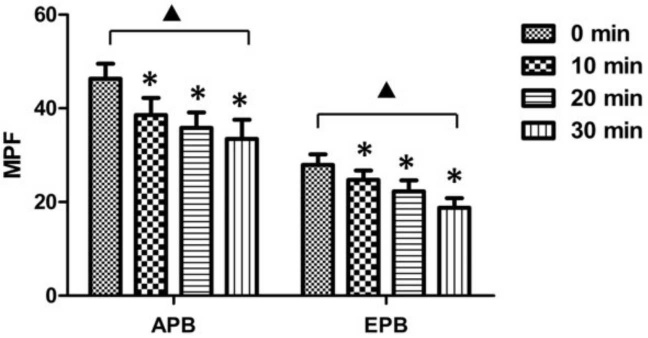

Figure 5. Mean power frequency (MPF) of the abductor pollicis brevis (APB) and extensor pollicis brevis (EPB) muscles over the test period. One-way analysis of variance was used to compare the MPF of the APB and EPB between 0 min, 10 min, 20 min and 30 min. Data are expressed as mean ± SD. ▲$P < 0.05$ among 0 min, 10 min, 20 min and 30 min. *$P < 0.05$ versus 0 min (*post-hoc* analysis).

($P < 0.05$). The *post-hoc* analysis showed that the mean ± SD MPF was significantly decreased at 10 min, 20 min and 30 min when compared with baseline (0 min) ($P < 0.05$ for all comparisons). There was a significant difference between 10 min and 20 min ($P = 0.038$). Similarly, there was also a significant difference between 20 min and 30 min ($P = 0.027$).

Discussion

The results of this current study demonstrated that repeated, quick movements of the thumb led to muscle fatigue, which suggests that this type of repetitive motion for prolonged periods of time might result in an accumulation of muscular injuries. A previous study demonstrated that nearly one in five adults had symptoms of musculoskeletal disorders associated with smartphone use in the past and pain had increased with time.[21] Musculoskeletal disorders are thought to be the result of fatigue failure of the musculoskeletal tissues.[22] Research has also demonstrated that muscle fatigue can easily develop into chronic pain.[23] It has been shown *in vivo* that the structure of musculoskeletal tissue can be changed when a repetitive load is applied.[24]

Traditionally, repetitive movements of the thumb frequently occurred in crafts men and women, leading to many physical problems such as arthritis, tendon rupture and tenosynovitis.[25–27] Muscle fatigue can be caused by work that requires repeated movements in static postures.[28] However, this kind of repetitive work can be distinguished from the repetitive thumb movements of smartphone users because moving the thumb requires less power. People generated less power while operating their smartphones in this study. It is presumed that rapid, repetitive muscle movements required more oxygen and energy supply.

Insufficient supply of oxygen and nutrients through the blood circulation results in changes to the metabolism of the muscles, structural and energetic changes in the organism and changes in the efficiency of the nervous system, leading to muscle fatigue.[29] In this current study, the local muscle fatigue was measured using sEMG signals. The advantage of measuring sEMG signals is that it is non-invasive and provides real-time monitoring. The frequency domain was used to analyse the data because it was not restricted by normal muscle contraction.

The current study observed that although the VAS scores showed a significant difference before and after the experiment was terminated, the changes were not as subtle as those observed for the MDF. This finding suggests that the volunteers did not feel uncomfortable before muscle fatigue occurred. These current results were similar to those of other studies. For example, it was reported that playing games might stabilize people's emotions and reduce pain, which means that as smartphone use increases, the pain associated with musculoskeletal disorders might develop.[30] In addition, research has shown that if there is no expected physiological negative pain feedback, excessive smartphone gaming might lead to tendon attenuation and subsequent tendon rupture.[31]

The current results showed that the extensor pollicis brevis was more susceptible to muscle fatigue compared with the abductor pollicis brevis. The distinct appearance of the two muscles might be due to the different composition of the muscle fibres, with type I (slow twitch) fibres being the dominant type in the abductor pollicis brevis muscle.[32] Traditionally, one of the main functions of the thumb is to grip. Therefore, the abductor pollicis brevis muscle plays an essential role during thumb movements. However, when operating a smartphone, the extension of the thumb is also required. This leads to excessive use of the extensor pollicis brevis.

This current study had a number of limitations. First, the study population was limited to young adults aged 20–30 years. Secondly, the subjects were analysed while they were using a smartphone for just a short period of time (30 min). Thirdly, the two muscles studied are only part of the muscle system associated with thumb movements, but some of the other muscles that are involved cannot be measured by sEMG. Therefore, the study did not fully investigate the changes to muscles associated with thumb use during smartphone gaming and other daily use, which typically last for a longer period of time. Further research is required in a larger study population with a wider range of ages.

In conclusion, this current study found that after 30 min of continuously playing a game on a smartphone, the MDF of the abductor pollicis brevis and extensor pollicis brevis muscles had significantly reduced. In addition, the VAS scores for discomfort had increased significantly after 30 min of playing the smartphone game. Similarly, the MPF of the abductor pollicis brevis and extensor pollicis brevis muscles gradually reduced during the 30-min game duration. The findings of this study suggest that playing games on smartphones is harmful to the muscles associated with thumb movements. In our opinion, continuous gaming time should be kept below 20 min and the player should find a way to play the game that reduces their dependence on thumb movements.

Declaration of conflicting interest

The authors declare that there are no conflicts of interest.

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