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Original Article

Effect of duration of smartphone use on muscle fatigue and pain caused by forward head posture in adults

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Abstract. [Purpose] The effect of duration of smartphone use on neck and shoulder muscle fatigue and pain was investigated in adults with forward head posture. [Subjects and Methods] Thirty-four adults with forward head posture were classified into groups by duration of smartphone use: 11 used a smartphone for 10 minutes each (group 1), 12 for 20 minutes each (group 2), and 11 for 30 minutes each (group 3). Fatigue cervical erector spinae and upper trapezius muscles was measured by electromyography, and pain before and after the experiment was evaluated using Visual Analog Scale (VAS) scores. [Results] There was a significant difference in the degree of fatigue in the left upper trapezius muscles in group 2 and left cervical erector spinae and bilateral upper trapeziuses group 3. There was a significant difference in fatigue in the left upper trapezius in groups 1 and 3. The VAS showed significant differences in all groups before and after the experiment and between groups 1 and 3. [Conclusion] Pain and fatigue worsened with longer smartphone use. This study provided data on the proper duration of smartphone use. Correct posture and breaks of at least 20 minutes are recommend when using smartphones.

Key words: Forward head posture, Muscle fatigue, Smart phone

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INTRODUCTION

Smartphones combine a variety of digital devices, unlike conventional telephones. Smartphones use has led to rapid changes in society by satisfying consumers needs, and their convenience has greatly expanded their availability. Working on computers and operating smartphones for long periods of time promote repetitive use of certain muscles, resulting in muscle fiber injury, cumulative damage from acute trauma, and myogenic tonus, which occur most often in the neck and shoulders[1)].

Repetitive and cumulative trauma to the neck and shoulder causes forward head posture (FHP), a specific musculoskeletal abnormality[2)]. FHP weakens the deep cervical flexor muscle, the midthoracic rhomboid muscle for scapular retraction, and the mid and lower trapezius muscles. FHP also shortens the pectoralis major and neck extension muscles. Upper trapezius muscle activity is increased more in FHP than in correct anatomic positions, and most patients complain of pain from muscle overuse[3)].

According to Shim and Zhu[4)], fatigue and stress in the neck and shoulders occur more easily with use of touch-screen computers than with desktops because small-monitor devices such as smart phones and tablet PCs cause people to look down and to slouch more than with desktops[5)].

Smartphone use in a static position and with an unsupported arm could bring about abnormal alignment of the neck and shoulders. Because smartphones have small monitors that are typically held downward near the laps, users must bend their heads to see the screens, increasing activity in the neck extensor muscles overloading the neck and shoulders increases muscle fatigue, decreases work capacity and affects the musculoskeletal system[2, 3)].

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There are a number of studies on posture and motion with computer, laptop and smartphones use. However, studies are lacking on appropriate durations of use. This study aimed to investigated the effect of the duration of smartphone use in adults with FHP and the onset of fatigue and pain in neck and shoulder muscles.

Objective and quantitative data were obtained regarding appropriate duration of smartphone use in adults with FHP.

SUBJECTS AND METHODS

A total of 34 patients in their 20s and 30s were enrolled whose tragus was located on the left side rather than at the lateral acromion angle on radiography in a lateral cervical view[6].

The procedure and purpose of the study were excluded to the subjects, who voluntarily consented to participate. This study excluded individuals with neck pain and those with congenital deformities, serious surgical or neurological diseases, limb injuries, or limb pain in the prior 6 months. The study received approval from the Korea Kyungnam University institutional review board (IRB 1040460-A-2014-022) before participant recruitment began.

The average age, height, and weight of subjects was 26.20 ± 5.45 years, 167.24 ± 7.73 cm, and 60.87 ± 8.03 kg, respectively. Mean VAS score was 1.15 ± 0.87 with no significant differences.

A goniometer was used on all subjects in order to quantify posture as they began to use a smartphones.

The subjects sat comfortably on a stool with their feet on the floor, knee and hip joints at right angles, and trunk upright. Upper arms were raised to clavicle level to prevent lumbar overflexion.

Subjects were allowed to use message services, KakaoTalk, games, and the Internet with no limitations during smartphone use[7, 8].

They were also instructed to focus only on phone use without paying attention to maintaining neck and lumbar posture. An electromyograms (EMG) was performed initially for one minute and then for another minute immediately after phone use began. Pain was assessed before and after smartphone use using the VAS.

A Galaxy S4 LTE-A smartphone (SHV-E330S, Samsung Electronics Co., Ltd., Seoul, Korea) was used in this experiment.

To collect the surface EMG signal from the cervical erector spinae and upper trapezius muscles, which support stability around the neck and shoulders, a Trigono™ Wireless EMG system (Delsys Inc., Boston, MA, USA) was used[9].

The sampling rate was set at 2,000 Hz, and the bandwidth for the EMG signal noise rejection was set at 20–450 Hz.

The analog signals of each muscle were collected and analyzed by Delsys EMG Works Acquisition software for PC, based on digital signals that were wirelessly sent from the Trigono base station.

Before we attached the electrodes, we exfoliated the skin using sandpaper and then cleaned it with alcohol swabs in order to reduce the muscle resistance to the EMG signals.

The surface EMG electrodes were attached 1–2.5 cm apart in parallel with both the cervical erector spinae and upper trapezius muscle fibers.

The EMG sensors were attached around both C4 areas for the cervical erector spinae and slightly outward from the midline between C7 and the acromioclavicular joint for the upper trapezius muscle[10].

Data from each muscle before and after the experiment were interpreted by mathematic FFT (Fast Fourier Transform) and spectrum analysis, and the median frequency was used as an index for muscle fatigue.

With high muscle fatigue, the frequency spectrum moves toward the lower end[11].

The collected data were processed with SPSS Version 22.0 using a paired-t test to analyze muscle fatigue, changes in FHP, and severity of pain before and after the experiment in the three groups, and one-way analysis of variance (ANOVA) was used to compare the muscle fatigue, change in the FHP, and pain by elapsed phone use time. Least Significant Differince (LSD) was used for the post hoc test, and the level of significance was $\alpha=0.05$.

RESULTS

In group 2, there was a significant difference in muscle fatigue before (72.73 ± 12.19) and after (70.08 ± 11.24) the experiment in the left upper trapezius muscle ($p<0.05$) in group 3, the significant difference was observed in the left cervical erector spinae (before: 68.61 ± 6.59; after: 61.93 ± 6.98) ($p<0.05$).

There were other significant differences in comparisons before and after the experiment: 71.62 ± 8.73 and 62.90 ± 7.07 in the left upper trapezius muscle and 75.44 ± 6.30 and 66.17 ± 8.26 in the right upper trapezius muscle ($p<0.05$) (Table 1).

There was a significant difference in muscle fatigue in the left upper trapezius between group 1 (75.12 ± 9.60) and group 3 (62.90 ± 7.07) (Table 2).

All VAS scores before and after the experiment increased, with significance show for all three groups ($p<0.05$).

DISCUSSION

Smartphones are used frequently in daily life, and affect users both physically and psychologically.

A survey of adults over age 20 by Eom et al.[12] revealed that 18.8% had experienced symptoms related to a musculoskeletal disorder from smart phone use, and that pain had increased with duration of use.

Table 1. Fatigue measurements by group (N=34)

Group		Pre	Post
		Mean ± standard deviation	Mean ± standard deviation
Group 1	LCES	67.8 ± 4.5	65.4 ± 4.9
	RCES	62.2 ± 4.1	61.7 ± 4.6
	LUT	76.0 ± 9.3	75.1 ± 9.6
	RUT	69.0 ± 11.1	67.6 ± 11.3
Group 2	LCES	66.1 ± 5.7	64.7 ± 5.0
	RCES	63.5 ± 9.8	66.3 ± 9.8
	LUT	72.7 ± 12.2	70.1 ± 11.2
	RUT	71.7 ± 8.8	70.8 ± 9.0
Group 3	LCES	68.6 ± 6.6	61.9 ± 7.0
	RCES	64.2 ± 5.4	60.8 ± 8.4
	LUT	71.6 ± 8.7	62.9 ± 7.1
	RUT	75.4 ± 6.3	66.2 ± 8.3

$p<0.05$. LCES: left cervical erector spinae, RCES: right cervical erector spinae, LUT: left upper trapezius, RUT: right upper trapezius

Table 2. Fatigue measurements within each group (N=34)

		Group 1 (N=11)	Group 2 (N=12)	Group 3 (N=11)
		Mean ± standard deviation	Mean ± standard deviation	Mean ± standard deviation
Pre	LCES	67.8 ± 4.5	66.6 ± 5.7	68.6 ± 6.6
	RCES	62.2 ± 4.1	63.5 ± 10.0	64.2 ± 5.4
	LUT	76.4 ± 10.3	72.7 ± 12.2	71.6 ± 8.7
	RUT	69.0 ± 11.1	71.7 ± 8.8	75.4 ± 6.3
Post	LCES	65.4 ± 4.9	64.7 ± 5.0	61.9 ± 7.0
	RCES	61.6 ± 4.6	62.3 ± 9.8	60.8 ± 8.4
	LUT	75.1 ± 9.6	70.1 ± 11.2	62.9 ± 7.1
	RUT	67.6 ± 11.3	70.8 ± 9.0	66.2 ± 8.3

In this study, we investigated muscle fatigue by measuring median frequency. The group that used the phone for 10 minutes showed decreased median frequency of fatigue in all of the muscles studied, but without significance ($p>0.05$). In the 20-minute group, there was a slight decrement in median frequency, and fatigue decreased significantly in the left upper trapezius ($p<0.05$).

There were no significant differences in muscle fatigue in the right cervical erector spinae ($p>0.05$), but significant differences were noted in the left cervical erector spinae and the left and right upper trapezius muscles ($p<0.05$) in the group that used the phone for 30 minutes.

A significant difference in muscle fatigue in the left upper trapezius was shown between the 10-minute and 30- minute groups.

In Park et al.[13)], participants who used a smartphone for 20 minutes showed median fatigue frequency decrements both the upper trapezius and cervical erector spinae muscles, and also reported more load on the right shoulder than the left because the right shoulder was used more often . However, in our study, the 20-minute group presented significant differences in fatigue in the left upper trapezius ($p<0.05$), and the 30-minute group showed significant differences in fatigue in their left cervical erector spinae and left and right upper trapezius ($p<0.05$).

Previous studies revealed that smartphone overuse places the head in an unvarying posture and that continuous muscle contraction then brings about muscle weakness and fatigue that could easily develop into chronic cervical pain[14)].

In addition, continuous static pressure on specific sites could also increase muscle fatigue and pain[15)].

Kraemer et al.[16)] reported that muscle fatigue is caused by work that requires repeated movement in static postures.

Park et al.[13)] studied male subjects using a game that could be operated by both hands. In this study, we enrolled both male and female participants, and allowed them to use the phones freely for web surfing and messaging, rather than having them perform only one activity. The subjects held the phones in their left hands and used their right hands infrequently, which led to a greater load on the shoulder that performed the same motion.

All three groups showed significant differences in VAS scores after the experiment, and there was also a significant difference between the 10-minute and 30-minute groups ($p<0.05$).

Lee and Song[17] studied pain severity according to smartphone use duration, and they reported significant differences in reading, concentration, and headaches, although these could have been transient symptoms from the smartphone use.

The participants in this study mostly used their smartphones lowered toward their laps, so that they maintained fixed postures with their necks flexed. According to Kim et al.[18], looking downward promotes muscle fatigue more easily than does looking upward.

Most subjects were using the phones in the wrong position, which could have negatively affected muscles and joints. Combined with the wrong position, double and even triple myotonia and myalgia could be triggered[19]. Although we investigated only one session per subject, if adults with FHP continuously use smartphones, they could be exposed to cumulative pain.

There is a lack of studies regarding the physical effects of long-term smartphone use. Thus, we investigated muscle fatigue and VAS scores according to smartphone use time: 10 minutes, 20 minutes, or 30 minutes.

This study does have limitations. We observed differences with only short-term use but not long-term or continuous use. In addition, the subjects were limited to adults with FHP, so we did not have the opportunity to compare this group to those with normal posture, and also did not analyze differences based on different phone use postures.

Additional studies are needed regarding cumulative trauma, posture changes in the neck and shoulders, and treatment methods for related disorders.

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