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Original Article

An analysis of the activity and muscle fatigue of the muscles around the neck under the three most frequent postures while using a smartphone

Jung-Hyun Choi, PT, PhD[1)], Min-Ho Jung, PT[1)], Kyung-Tae Yoo, PT, PhD[1)*]

[1)] *Department of Physical Therapy, Institute for Elderly Health and Welfare, Namseoul University: 21 Maeju-ri, Sungwan-eup, Seobuk-Gu, Chonan-Si 331-707, Republic of Korea*

Abstract. [Purpose] The purpose of this study was to identify changes in the activity and fatigue of the splenius capitis and upper trapezius muscles, which are agonists to the muscles supporting the head, under the three postures most frequently adopted while using a smartphone. [Subjects and Methods] The subjects were 15 college students in their 20s. They formed a single group and had to adopt three different postures (maximum bending, middle bending, and neutral). While the 15 subjects maintained the postures, muscle activity and fatigue were measured using surface electromyography. [Results] Comparison of the muscle fatigue caused by each posture showed statistically significant differences for the right splenius capitis, left splenius capitis, and left upper trapezius muscles. In addition, maintaining the maximum bending posture while using a smartphone resulted in higher levels of fatigue in the right splenius capitis, left splenius capitis, and left upper trapezius muscles compared with those for the middle bending posture. [Conclusion] Therefore, this study suggests that individuals should bend their neck slightly when using a smartphone, rather than bending it too much, or keep their neck straight to reduce fatigue of the cervical erector muscles.

Key words: Smartphone, Muscle activity, Muscle fatigue

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INTRODUCTION

When using a smartphone on public transportation, individuals typically lower their heads. When they look at the smartphone screen in this posture for a long time, they experience shoulder and neck pain, and occasionally complain of headaches[1)]. When continuous loads are applied in a static posture with the head kept lowered, musculoskeletal diseases may develop[2)]. When the head is lowered, the cervical vertebrae become straight. This may lead to myofascial pain syndrome by causing stress and excessive tension in the muscles around the neck and shoulders[3)]. Myofascial pain syndrome may develop along with tissue damage, or abnormal conditions may occur as a result of abrupt stress or excessive tension on the muscles[4)].

Jobs that require sitting at a desk for long hours, such as computer and office work, negatively influence the neck and shoulder muscles[5)]. In addition, changes in the strength of the deep cervical flexors, endurance, and the location of the lower jaw have been shown in individuals with neck pain, compared with individuals without neck pain[6)].

Kieine and Schumman studied the activity of the upper trapezius associated with changes in shoulder postures, and Tepper studied the effects of computer work on the activity of the upper trapezius[7, 8)]. These studies found that incorrect postures cause excessive tension in the upper trapezius and the surrounding muscles. Such excessive tension is known to cause pain by developing abnormal forces in the skeletal system[9, 10)].

The measurement of cervical-bent postures of women using computers showed increases in the head tilting of women complaining of pain[11)]. A large proportion of the existing studies have focused on the visual display terminal (VDT) that is commonly seen with office computers. In addition, some studies have examined the fatigue and activity of cervical muscles

*Corresponding author. Kyung-Tae Yoo (E-mail: taeyoo88@nsu.ac.kr)

Table 1. General characteristics of the subjects

	Meanect
Age (yrs)	23.6 ± 2.4
Height (cm)	174.7 ± 7.6
Weight (kg)	69.2 ± 11.9
Gender (men/women)	8/7

Table 2. Locations for attachment of electrodes

Muscle	Location
Splenius capitis	Midpoint between the spinous process of C7 and the peak of the shoulder blade
Upper trapezius	The point 2 cm away from the lateral side of T4

under the postures adopted while using a microscope in the workplace as well as the activity of cervical muscles while individuals were watching a digital multimedia broadcasting (DMB) phone[12–14]. Smartphones and tablets have recently drawn a great amount of attention and have become almost daily necessities; however, these devices and other similar new devices may cause cervical deformities when used for extended hours. Therefore, multiple studies on changes in the activity and fatigue of cervical erectors in the postures of smartphone users should be conducted in various environments to prevent skeletal diseases. Therefore, this study was conducted to investigate the changes in the activity and fatigue of the splenius capitis and upper trapezius agonistic muscles, the muscles that support the head, under the three postures adopted most frequently while using a smartphone.

SUBJECTS AND METHODS

In this study, the three common postures while using a smartphone were considered as independent variables, and the corresponding muscle activity and fatigue as dependent variables. The experiment was based on a within-group design in which tests were performed on a single group under three different conditions. The subjects were 15 college students in their 20s who were given complete explanations about the experiment in advance. The subjects were required to be healthy individuals with no history of spinal damage or undergoing any surgery, and no hand or wrist injuries or other surgeries during the preceding six months. All participants were instructed about potential risks and experimental design, and were provided with an informed consent form to sign prior to participation, with the knowledge that they could withdraw at any time. The Ethics Committee of Namseoul University in Korea approved the study. The IRB approval number is Research-NSU-1041479-201311-HR-002. General characteristics of the subjects are shown in Table 1.

The muscles targeted for measuring muscle activity were the splenius capitis and upper trapezius, which are the agonistic muscles for cervical extension and are known to cause neck pain[11, 15]. The researcher identified the location of these muscles by activating the areas around the subjects' relevant muscles, and then attached electrodes, as shown in Table 2, by referring to previous studies[15]. The electrodes were attached after sterilization with alcohol would be adequate, and the electrodes were attached after sterilization with alcohol using cotton balls. The markers of a three-dimensional motion analyzer were attached to objectively determine the maximum cervical bending posture, middle cervical bending posture, and neutral posture. The markers were attached to the center of the forehead, the seventh cervical vertebra (C7), and the seventh thoracic vertebra (T7).

A chair of the same height as that in a subway train was prepared, and each subject was instructed to sit in the chair with his or her hips touching the back of the chair and the pelvis fixed. In the maximum bending posture, the subject was instructed to place a smartphone as high as the subject's elbow and grab it with both hands 5 cm away from the trunk (Fig. 1).

In the middle bending posture, the subject's her upper arms were close to the trunk and the neck was bent slightly in a comfortable manner (Fig. 2). In the neutral posture, the edge of the upper part of the smartphone's screen and the subject's eye level were kept horizontal (Fig. 3). The average degree of neck-bending during each of the three postures was obtained by measuring and averaging the degrees of the three motion markers for each posture during preliminary tests on five subjects. The average degree of neck-bending was 100° for the maximum bending posture, 122° for the middle bending posture, and 131° for the neutral posture. A height-adjustable table was prepared to support the subjects' arms during the postures to avoid fatigue in the arms[16]. Surface electromyography (sEMG) was used to measure the 15 subjects while they remained in the three postures, and measurements were performed randomly to reduce errors caused by measuring in the sequence of the postures. While each subject was adopting each posture for five minutes, he or she was instructed to continuously type the sentences "The Blue House is not seen from the outside." and "Korean people speak." on the smartphone. After five minutes, the subject's muscle activity and fatigue were measured. After being measured under one condition, each subject was provided with a 24-hour break to recover from fatigue, and then was tested under the next condition[17]. In this study, a chair having the same height as that of a seat in a subway train and a height-adjustable vibrating table was used. The smartphone used during the experiment was one that is commonly used by Koreans, and a three-dimensional motion analyzer (Smart E, Italy) was employed to measure the degree of bending during each posture. A wireless electrode EMG system (Free EMG, BTE, Italy) was used as an EMG device to identify the muscle activity and fatigue of the splenius capitis and upper trapezius. EMG data from the maximum cervical bending postures, middle cervical bending postures, and neutral postures were applied into root mean square (RMS) for five minutes, and mean values were also calculated for one min and were normalized by % RVC[18].

The study data were analyzed statistically, using SPSS version 18.0 for Windows. The Kolmogorov-Smirnov test was

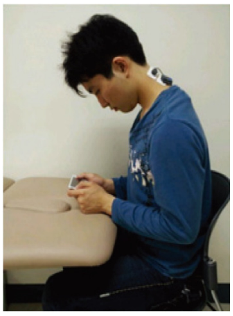

Fig. 1. Maximum bending posture

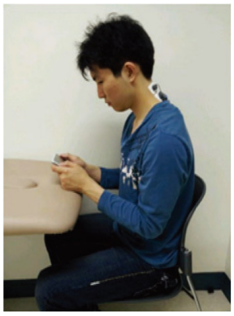

Fig. 2. Middle bending posture

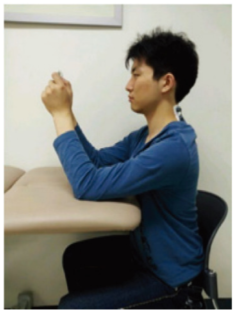

Fig. 3. Neutral posture

used to confirm that the characteristics of the data used in this study represented normal distribution. An analysis of variance (ANOVA) test was conducted to compare the activity and fatigue of the cervical erector during the three different postures while using the smartphone. Scheffe's test was employed as a post-hoc test on the statistically significant differences between the muscle groups, and the statistical significance level for all data was set at α=0.05.

RESULTS

In terms of the differences in the muscle activity for each posture, the four muscles measured (right splenius capitis, right upper trapezius, left splenius capitis, left upper trapezius) did not show any statistically significant differences (Table 3).

The comparison of muscle fatigue among the postures showed statistically significant differences for the right splenius capitis, left splenius capitis, and left upper trapezius (Table 4).

DISCUSSION

The purpose of this study was to examine changes in muscle activity and fatigue under different postures while using a smartphone, because of their rapidly increasing use. In particular, Polakowska reported that cervical degenerative changes appear due to working postures, types of motions during work, and amplitude of vibration; Paccinni et al. reported that improper postures are associated with abnormal cervical curvatures[19, 20]. Therefore, one aim of this study was to provide basic data on correct postures while using a smartphone to prevent neck pain and deformation that can occur due to their extended use in undesirable postures. In terms of changes in muscle fatigue associated with postural changes during smartphone use, this study showed that the maximum bending posture resulted in significantly higher levels of muscle fatigue in the right splenius capitis, left splenius capitis, and left upper trapezius, compared with middle bending posture.

There were no significant differences in muscle activity in the right splenius capitis, left splenius capitis, and left upper trapezius among the three postures. Previous data demonstrated that work posture could cause musculoskeletal problems[21, 22]. However, there was no change in muscle activity because of the experimenter's tension by the awareness of experiments was not controlled and the realization of real long-time smart phone use was limited by measuring EMG signal for short smart phone using time of five minutes[21–23].This result is consistent with that of Jung's study, in which during the head-neck bending exercise of the cervical lordosis group, kyphosis group, and hyperlordosis group, a comparative analysis was performed on the activity of the deep flexor and the sternocleidomastoid using pressure and ultrasonic images, and a higher level of pressure led to a corresponding increase in the activity of the deep cervical flexor[24]. As suggested by Harms-Ringdal et al., these results may be because muscles exercise their forces in the opposite direction to fight opposite movements[25]. However, the results of this study differ from those of some previous studies. For example, Thuresson compared muscle activity during the cervical neutral posture and cervical 20° forward bending posture on the axis of C7–T1, and found a higher level of muscle activity during the 20° forward bending. In addition, Yoo compared muscle activity during the neutral posture and bending posture, and reported a statistically significant higher level of muscle activity during the bending posture[17, 26]. According to the results of Villanueva's study, in which the trunk's movements affected the activity of the muscles that surround it, continuous use of smartphone in the present study may have caused contractions of muscles in the hands, wrists, and arms. Thus, muscle activation in the cervical erector was not only confined to the cervical area but also spread into the hands, wrists, and arms, thereby resulting in no statistically significant changes in muscle activity[27].

In this study, the muscle fatigue under the maximum bending posture and neutral posture showed similar levels of increases, although this result was not statistically significant. Some studies have reported that a smaller degree of joint flexion led to a statistically significant higher level of muscle fatigue, which may also support the present study result[28, 29]. In addition, a smaller degree of cervical flexion increases the level of head-lowering, and the head is then influenced by gravity to a larger extent[30]. Here, a larger load is applied to the cervical erector to support the relevant position, which may cause increased levels of fatigue.

Table 3. Comparison of the muscle activity under the postures

Muscle	Posture	Mean	Standard Deviation
	Neutral posture	14.2	7.4
Right splenius capitis	Middle bending posture	13.4	8.2
	Maximum bending posture	18.8	25.9
	Neutral posture	8.9	5.8
Right upper trapezius	Middle bending posture	5.5	3.9
	Maximum bending posture	7.1	5.7
	Neutral posture	14.2	9.9
Left splenius capitis	Middle bending posture	13.1	11.0
	Maximum bending posture	13.7	11.0
	Neutral posture	7.7	4.4
Left upper trapezius	Middle bending posture	5.6	3.9
	Maximum bending posture	7.9	1.2

Table 4. Comparison of the muscle activity under the postures

Muscle	Posture	Mean	Standard deviation
	Neutral posture	0.2	0.0
Right splenius capitis[†]	Middle bending posture[2]	0.2	0.0
	Maximum bending posture[1]	0.2	0.0
	Neutral posture	0.2	0.0
Right upper trapezius	Middle bending posture	0.2	0.0
	Maximum bending posture	0.2	0.0
	Neutral posture	0.2	0.0
Left splenius capitis[†]	Middle bending posture[2]	0.2	0.0
	Maximum bending posture[1]	0.2	0.0
	Neutral posture	0.2	0.0
Left upper trapezius[†]	Middle bending posture[2]	0.2	0.0
	Maximum bending posture[1]	0.2	0.0

Values are shown as mean ± SD, $*p<0.05$. [†]Significant difference in three postures. [1]: Significantly different compared with middle bending posture. [2]: Significantly different compared with maximum bending posture.

The present study has some limitations. First, the subjects were measured while they were using a smartphone for a short time of five minutes; therefore, the study did not fully reproduce the situation of individuals using their smartphones in the subway, which is typically for longer periods. In addition, the subjects were 15 college students in their 20s, and thus, the results derived cannot be generalized for various age groups. Moreover, it was difficult to control the subjects' daily activities during the 24-hour break provided after each measurement. Consequently, a follow-up study should fully reproduce the conditions in which individuals use their smartphones on public transportation, and test subjects from various age groups for longer durations of smartphone use.

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