The effects of smart phone gaming duration on muscle activation and spinal posture: Pilot study

Article *in* Physiotherapy Theory and Practice · June 2017

DOI: 10.1080/09593985.2017.1328716

4 authors, including:

Joo-hee Park
Yonsei University

Sun-Young Kang
Yonsei University

Hye-Seon Jeon
Yonsei University

PHYSIOTHERAPY THEORY AND PRACTICE
https://doi.org/10.1080/09593985.2017.1328716

Check for updates

The effects of smart phone gaming duration on muscle activation and spinal posture: Pilot study

Joo-Hee Park, MS[a], Sun-Young Kang, PhD[a], Sa-Gyeom Lee, PhD[b], and Hye-Seon Jeon, PhD[a]

[a]Department of Physical Therapy, Yonsei University, Wonju, Kangwon-do, Republic of Korea; [b]Department of Physical Therapy, Suwon Women's University, Bongdam-eup Hwaseong, Kyonggi-Do, Republic of Korea

ABSTRACT

This study investigates changes in the posture angles of the neck and trunk, together with changes in the muscle activation of users, at the start of and at 5, 10, and 15 minutes of smartphone use. Eighteen males participated in this study. Surface electromyography (EMG) and a digital camera were used to measure the muscle activation and angular changes of the neck and trunk of participants during smartphone use for a period of 16 minutes. Neck and trunk flexion significantly increased at 5, 10, and 15 minutes ($p < 0.05$) in comparison with the neck and trunk flexion of participants at the start of smartphone usage. The EMG activation and 10th% amplitude probability distribution function (APDF) values of the bilateral cervical erector spinae at 5–6, 10–11, and 15–16 minutes of usage ($p < 0.05$) were also significantly greater than at the start of usage. The EMG activation of the bilateral thoracic erector spinae and lower trapezius was significantly decreased at 5–6, 10–11, and 15–16 minutes of usage ($p < 0.05$). Smartphone use induced more flexed posture on the neck and trunk than other visual display terminal (VDT) work. Smartphone use also changed posture and muscle activation within a relatively short amount of time, just 5 minutes. Pain after 16 minutes of smartphone use was also observed. Thus, clinicians should consider the influences of smartphone use in posture and muscle activity in evaluation, intervention, and prevention of neck and trunk conditions.

ARTICLE HISTORY
Received 23 September 2015
Revised 4 July 2016
Accepted 25 July 2016

KEYWORDS
Electromyography; posture; smartphone

Introduction

As the use of visual display terminals (VDTs) such as desktop computer, laptop computer, tablet, and smartphone increases, the various musculoskeletal signs and symptoms have become an important social health issue (Spallek et al., 2010; Yoo and Kim, 2010; Zhu and Shin, 2012). In particular, forward head posture (FHP) and or flexed posture (slouched posture) are the most frequently observed musculoskeletal consequences of extended exposure to VDTs (Brandt et al., 2004; Burgess-Limerick, Plooy, Fraser, and Ankrum, 1999; Carter and Banister, 1994; Fujimaki and Mitsuya, 2002; Gigante et al., 2004; Marcus et al., 2002). According to a survey in 2010, 59% of Americans accessed the internet through mobile devices, and the use of internet accessible devices has increased by 8% compared to 2009 (Smith, 2010). Thus, a number of studies have examined the differential influences of working on small sized mobile devices such as laptop computers or tablets (compared to desktop computers) on the head and trunk postures of users (Seghers, Jochem, and Spaepen, 2003; Straker, Jones, and Miller, 1997; Szeto and Lee, 2002). Previous study reported that the postural problems are more common and related symptoms are worse, in small computer users compared to desktop computer users by maintaining inappropriate posture, because the distance maintained between the eyes and the screen should be relatively short in order for a user to concentrate on the small size of the text and pictures (Szeto and Lee, 2002).

According to the 2015 Pew Internet and American Life Project, 64% of Americans owned smartphones at the time of the project, up from 58% in early 2014, and 85% of Americans ages 18–29 years owned a smartphone (Smith, 2015). Furthermore, 46% of smartphone users said that they could not live without a smartphone. The prevalence of smartphone devices has rapidly increased, to the point that the use of smartphones has become an indispensable part of our lives. However, there are only few existing studies on the musculoskeletal problems induced by smartphone use. A study by Lin and Peper (2009) reported that blood volume, pulse rate, temperature, skin conduction, and upper trapezius muscle activation increased, and 83%

CONTACT Hye-Seon Jeon hyeseonj@yonsei.ac.kr Department of Physical Therapy, Yonsei University, Wonju, 220-710 Kangwon-do, Republic of Korea
Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/iptp.

of the participants experienced neck and hand pain during texting on a cell phone. The work of Kim, Kang, and Kim (2013) states that just 300 seconds of smartphone use can bring about slouched posture and increased reposition error of the cervical spine, which supports that prolonged smartphone use induces inappropriate posture and changes proprioception. Furthermore, Park, Kang, and Jeon (2013) reported that 20 minutes of smartphone use can induce fatigue. However, there is no previous research on smartphone usage over time.

Therefore, the purposes of this study were to: 1) examine changes in the neck and trunk postures of smartphone users; 2) examine changes in the EMG activation of specific muscle groups, including the cervical erector spinae (CES), the upper trapezius (UT), lower trapezius (LT), and the thoracic erector spinae (TES) over a time period of 16 minutes, during which participants played a smartphone game for the purposes of analysis herein; and 3) examine the pain level induced by 16 minutes of playing the smartphone game.

Methods

Participants

A total of 18 male college students 21.18 ± 1.90 (range: 20 to 25) years of age volunteered for this study. We were unable to recruit female subjects for this study because females would not consent to the publication of unclothed upper body photographs per the requirements of this study. This is a sociocultural matter in Korea. In order to meet the inclusion criteria, the students were required to be right-hand-dominant, own a smartphone, and be familiar with the Anypang game. Students with congenital deformities, musculoskeletal or neurological conditions, or pain in their upper extremities and spine structures were excluded from this study. The duration of smartphone use was assessed by interview (i.e., How many hours have you used your smartphone; or How many hours have you played a smartphone game?). The average duration of smartphone use for the subjects was 3.93 ± 0.68 hours/day (Table 1). The present study was approved by the Yonsei University Wonju Campus Human Studies Committee. Subjects were given detailed information about the experiment, and they provided written informed consent prior to their participation.

Table 1. General characteristics of subjects (N = 18).

Characteristics	Mean (SD[a])
Age (years)	21.18 (1.90)
Height (cm)	174.37 (4.36)
Body mass (kg)	65.43 (5.97)
Daily smart phone usage (hours)	3.93 (0.68)

[a]Standard deviation.

Overview and procedures

For this study, all participants used a Galaxy Note smartphone (Samsung Electronics Co., Seoul, Korea), with specifications of 183 g and 151.1□80.5□9.4 mm. All participants played Anipang, a competitive online smartphone game, which requires high-level cognitive concentration and fast bilateral finger movements for players to get a high score.

Subjects sit on adjustable-height chair without armrests or back support. Subjects sat on the chair with 90-degree hip, knee and ankle flexion with their feet flat on the ground. A smartphone was held comfortably by subjects, in both hands, at the level of the sternum. In order to allow subjects to freely use the smartphone, the position of the neck was comfortable and not constrained. After settling comfortably in this position, the subjects were asked to fully focus on the online smartphone game for 16 minutes to achieve their highest score. Upon completion of the smartphone game, subjects were asked to record the level of pain in their neck and trunk areas using a visual analog scale (VAS) ranging from 0 to 10.

Kinematic analysis

A Sony Cyber-shot DSC-HX5V (Sony Co., Tokyo, Japan) was used to obtain the angular data. The camera was positioned on a tripod at a distance of 2 m from the center of the subject's chair. The lens of the camera was placed parallel to the right side of the sagittal plane of the subject, at a height that corresponded with the sternum. Infrared reflective markers were attached on the tragus of the right ear, the spinous process of the seventh cervical, the first lumbar vertebrae, the right acromion, and the right greater trochanter of the subject (Fernandez-de-Las-Penas, Alonso-Blanco, Cuadrado, and Pareja, 2006; Park and Yoo, 2012) (Figure 1). During the experimental procedure, still pictures were taken four times, including at the start of the experiment, at 5 minutes, at 10 minutes, and at 15 minutes after the start of the experiment (Figure 2). To obtain kinematic data from the pictures, a 2D motion analysis program (Simi Aktisys GmbH, Unterschleissheim, Germany) was used for digitizing and analysis. Neck angle was defined as the angle between the line from the right tragus to the 7th cervical spinous process and the vertical axis that passes C7 (Fujiwara, Tomita, Maeda, and Kunita, 2009; Park and Yoo, 2012). Therefore, an increased neck angle indicated an increase

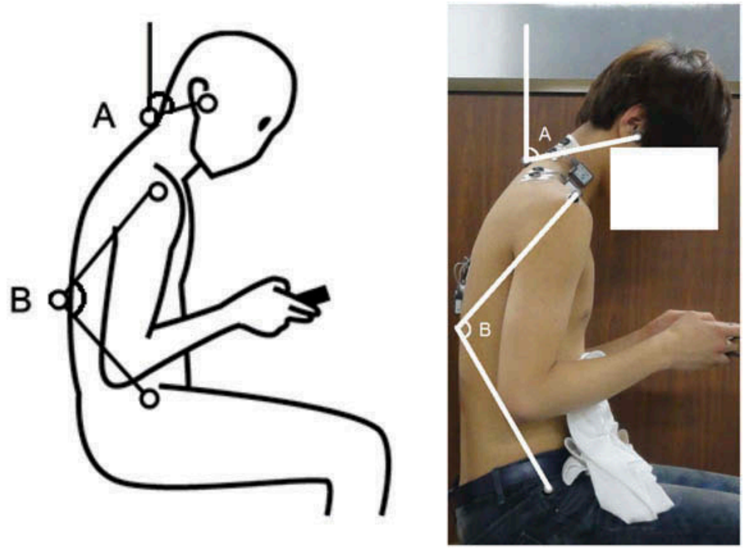

Figure 1. Definitions of the measured angles. A = Neck angle: an increase in neck angle represents an increase in neck flexion; B = Trunk angle: a decrease in trunk angle suggests increased flexion as opposed to the opposing reference extension.

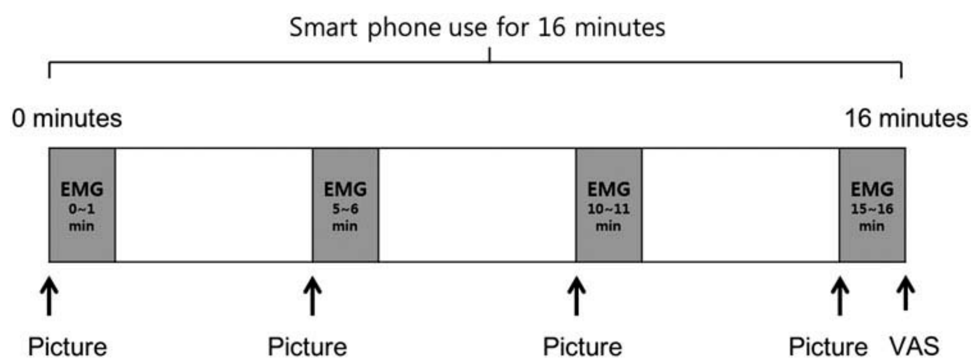

Figure 2. Duration of smart phone gaming experiment.

in neck flexion among subjects. Trunk angle was defined as the angle between the line from L1 to the right acromion and the line from L1 to the right greater trochanter. A greater trunk angle represented a relative increase in trunk extension among subjects (O'Sullivan et al., 2002; Park and Yoo, 2012).

Surface electromyography

EMG data were collected and analyzed using a Noraxon Telemyo 2400T system (Noraxon Inc., Scottsdale, AZ, USA). The EMG signals were collected at a sampling rate of 1000 Hz, band-pass filtered between 20 and 450 Hz, and notch filtered at 60 Hz. The digital signals of the EMG activation were full-wave rectified and represented as root mean square (RMS) values, with a 100ms epoch moving window (Jensen, Finsen, Hansen, and Christensen, 1999; Merletti and Parker, 2004). Eight hydrogel active electrodes with silver chloride surfaces were placed bilaterally on the CES, UT, LT, and TES muscles of subjects. Before the attachment of electrodes, the skin of subjects was prepared by shaving and abrading the skin with 70% ethyl alcohol. The CES electrodes were attached parallel to the spine, approximately 2 cm from the midline, over the muscle belly at the C4 level. The UT electrodes were placed just lateral to the muscle belly along the ridges of the shoulders, half way between the spinous process of the C7 and the lateral edges of the acromion. The electrodes of the LT were placed between the spine and medial edges of the scapulae. The electrodes were placed bilaterally on the TES muscle mass parallel to the spine (T10 through L1), 2 cm lateral to the spine (Criswell, 2010).

The EMG amplitudes of the measured muscles were represented as a percentage of the reference voluntary contraction (RVC) value. To get the averaged reference values, EMG data from each muscle were collected, while the subjects maintained a 90-degree shoulder abduction in the scapular plane for 15 seconds, holding a 1kg weight. Subjects repeated the above procedure three times, and RVC values of the middle five seconds of each trial were taken and averaged to calculate the % RVC value of each muscle (Ellegast et al., 2007; Hansson et al., 2000; Kim, Cho, and Shin, 2012). The EMG data of all the observed muscles were continuously collected over the course of 16 minutes, while the subjects performed the smartphone game.

The EMG data were selectively analyzed from each muscle using MyoResearch 1.08 software (Noraxon, Inc., Scottsdale, AZ, USA) at four different time periods over the course of the experiment, including the intervals of 0–1 minute, 5–6 minutes, 10–11 minutes, and 15–16 minutes. Mean RMS amplitudes and 10th% amplitude probability distribution function (APDF) values of the EMG signals were used for the analysis of data. The 10th %APDF values of CES muscles were calculated in this study using the MATLAB R2008a program (MathWorks Inc., Natick, MA, USA). The APDF of an EMG signal characterizes the distribution of the cumulative probability function at different amplitude levels for ergonomic investigation in cases when EMG amplitude levels fluctuate over time (Jonsson, 1982; Jonsson, Persson, and Kilbom, 1988). Among other APDF values, 10th %APDF values have been used as indirect indicators of muscle load during sustained sedentary work such as computer tasks (Szeto, Straker, and O'Sullivan, 2009). Jonsson (1982) asserted that APDF profile can be adopted differently according to type of work and level of muscle activity as indicators of musculoskeletal stress. The 10th %APDF value represents less than 2% maximum voluntary contraction (MVC) and considers this an important indicator of muscle load during sustained sedentary work such as computer use (Szeto, Straker, and O'Sullivan, 2009). Therefore, we used the 10th %APDF value to analyze muscle use during smartphone gaming, which is a relatively sustained sedentary activity.

Statistical analysis

One-way repeated measures analysis of variance (ANOVA) was used for comparative analysis of the subjects' neck and trunk angles over time. The independent variable was timed at four places, including at the start of the gaming experiment, and subsequently, at 5, 10, and 15 minutes during the experiment. Mean EMG amplitudes and 10th %APDF values of the CES, UT, LT, and TES muscle groups were also analyzed by one-way ANOVA. The independent variable was timed at four places, including 0–1 minute, 5–6 minutes, 10–11 minutes, and 15–16 minutes of the experiment. Because the data meet an assumption of sphericity, the Bonferroni correction was employed as a post hoc analysis in instances in which significant differences were observed. Paired t-test was performed to analyze cervical and thoracic VAS scores. Numerical data are shown as the mean ± SD. The level of statistical significance was established at $p < 0.05$.

Results

Neck and trunk angles

The flexion of both the neck and trunk of subjects at 5 minutes, 10 minutes, and 15 minutes of the gaming experiment was significantly greater in comparison with the flexion of the neck and trunk of subjects at the beginning of the experiment ($p < 0.05$). First, the neck angle of subjects increased as the time they spent playing the smartphone game increased (Figure 3) ($p = 0.000$). The neck flexion of subjects was approximately 66.01 ± 6.11 degrees at the start of the game, increasing over time to 79.19 ± 9.68 degrees (at 5 minutes) ($p = 0.001$), 84.44 ± 11.35 degrees (at 10 minutes) ($p = 0.000$), and 90.34 ± 11.18 degrees (at 15 minutes) ($p = 0.000$). Secondly, the trunk angle of subjects decreased as the time they spent playing the smartphone game increased ($p = 0.000$). The decrease in the angle of the trunk represents increased flexion of the trunk. Among subjects, the trunk angle was approximately 104.01 ± 8.37 degrees at the start of the gaming experiment, decreasing over the course of the experiment to 91.73 ± 11.38 degrees (at 5 minutes) ($p = 0.000$), 84.53 ± 10.38 degrees (at 10 minutes) ($p = 0.000$), and 81.65 ± 9.01 degrees (at 15 minutes) ($p = 0.000$).

EMG amplitudes

The bilateral CES EMG amplitudes increased significantly as the amount of smartphone usage increased (Figure 4). The CES EMG amplitudes at 5–6 minutes

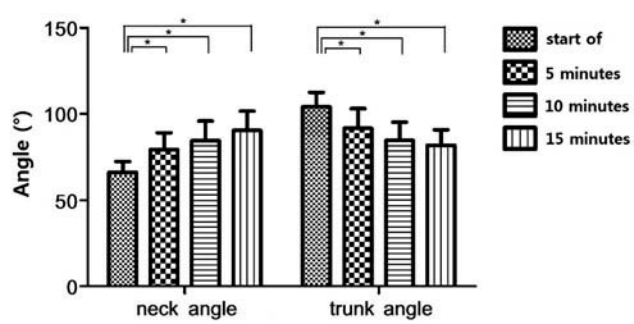

Figure 3. Comparison of mean neck and trunk angles during smartphone usage (*$p < 0.05$). Error bars represent standard deviation.

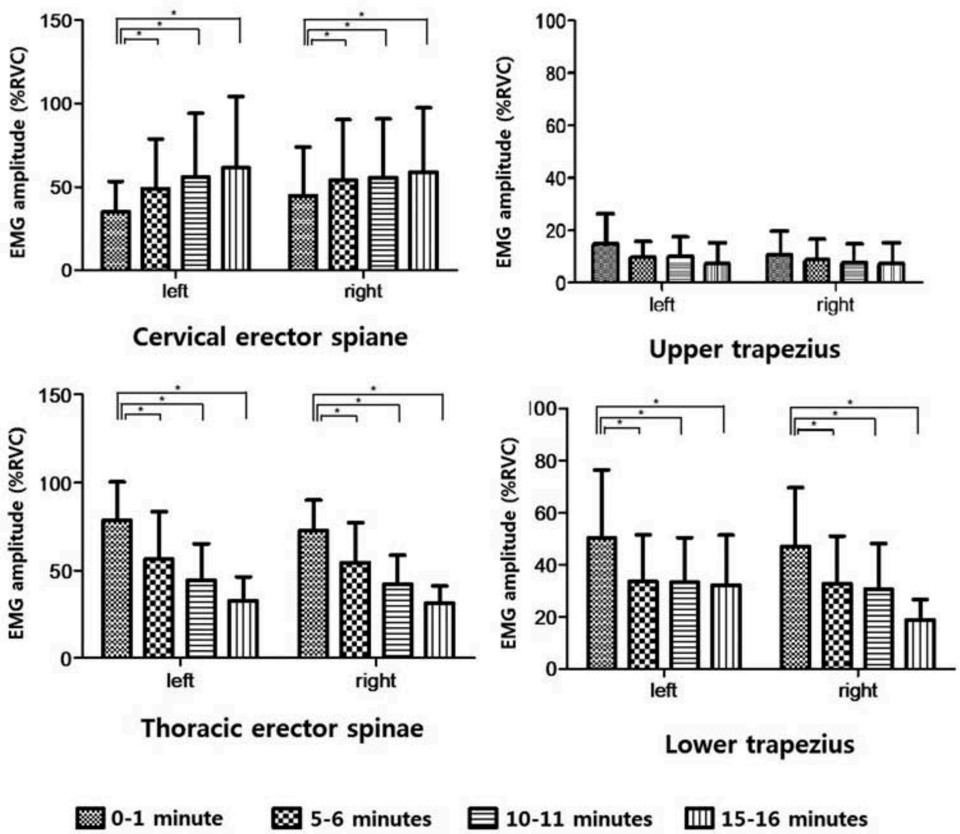

Figure 4. Comparison of mean EMG amplitudes (%RVC) of bilateral cervical erector spinae (CES), thoracic erector spinae (TES), upper trapezius (UT), and lower trapezius (LT) muscles while subjects played a smart phone game for a total of 16 minutes (*$p < 0.05$). Error bars represent standard deviation. RVC: reference voluntary contraction.

(right CES: $p = 0.002$, left CES: $p = 0.018$), 10–11 minutes (right CES: $p = 0.002$, left CES: $p = 0.015$), and 15–16 minutes (right CES: $p = 0.003$, left CES: $p = 0.006$) of smartphone use were significantly greater in comparison with the CES EMG amplitudes at the 0–1 minute interval of smartphone use. However, the bilateral LT and TES EMG amplitudes at 5–6 minutes (right LT: $p = 0.002$, left LT: $p = 0.024$, right TES: $p = 0.011$, left TES: $p = 0.012$), 10–11 minutes (right LT: $p = 0.003$, left LT: $p = 0.036$, right TES: $p = 0.000$, left TES: $p = 0.000$), and 15–16 minutes (right LT: $p = 0.000$, left LT: $p = 0.040$, right TES: $p = 0.000$, left TES: $p = 0.000$) statistically decreased from the EMG amplitudes at the start of the smartphone game playing experiment. No statistically significant difference was found in the UT EMG amplitudes among the four measurement times over the duration of smartphone game playing by subjects (right: $p = 0.120$, left: $p = 0.051$).

Amplitude probability distribution function values

A graph of APDF values for both sides of the CES muscle group shows that APDF values shifted to the right (A to D) as game time increased (Figure 5). However, APDF values of the TES and LT muscles shifted to the left as game time increased. All the observed muscles showed similar bilateral tendencies; however, Figure 5 includes only the changes in the APDF values of left-side muscles as game time increased. The APDF graph of the UT does not show any specific tendency of that particular muscles as game time increased. The 10th %APDF values of bilateral CES were significantly greater at 5–6 minutes (right: $p = 0.000$, left: $p = 0.018$), 10–11 minutes (right: $p = 0.000$, left: $p = 0.009$), and 15–16 minutes (right: $p = 0.000$, left: $p = 0.006$) in comparison with this value of bilateral CES at 0–1 minute (Figure 6). The 10th %APDF value of both sides of the TES muscle decreased as game time increased from this value at 0–1 minute (left TES 5–6 minutes: $p = 0.001$, left TES 10–11 minutes: $p = 0.000$, left TES 15–16 minutes: $p = 0.000$/right TES 5–6 minutes: $p = 0.110$, right TES 10–11 minutes: $p = 0.000$, right TES 15–16 minutes: $p = 0.000$). The 10th %APDF value of the left LT tended to decrease as game time increased according to findings about this value at 10–11 minute ($p = 0.029$) and 15–16 minutes ($p = 0.007$) of smartphone gaming compared with 0–1 minute of smartphone gaming. The APDF value of the

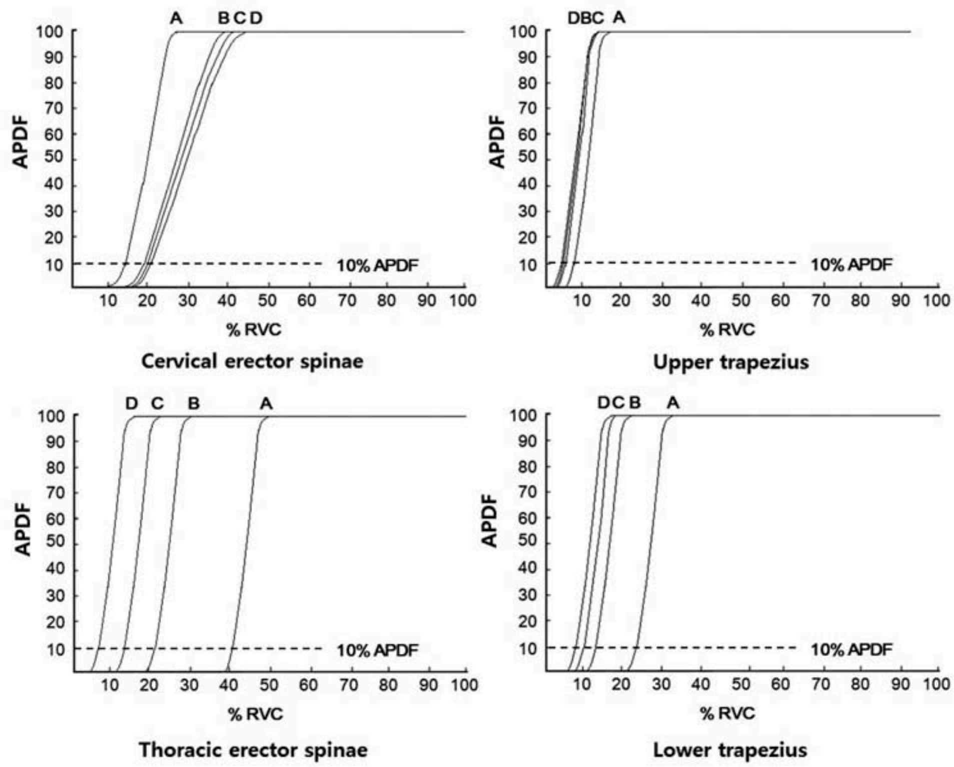

Figure 5. Amplitude probability distribution function (APDF) graphs according to game time. Curve A: 0-1 minute, curve B: 5-6 minutes, curve C: 10-11 minutes, curve D: 15-16 minutes. The dashed line represents 10th% APDF values. APDF: Amplitude probability distribution function, RVC: reference voluntary contraction.

right LT decreased significantly at 15–16 minutes of gaming in comparison with the APDF value of the right LT at 0–1 minute of gaming (p = 0.001). The 10th %APDF values of bilateral UT were not significantly different at any point in the duration of the smartphone gaming experiment in comparison with this value at 0–1 minute of game playing time (right: p = 0.101, left: p = 0.054).

Visual analog scale

Prior to playing the smartphone game, all subjects reported VAS scores of zero. Upon termination of 16 minutes of playing the smartphone game, all subjects reported some degree of neck (4.2 ± 1.3) and trunk pain (2.2 ± 1.2); further, paired t-tests of neck and trunk pain revealed statistically significant increases in the average VAS score ($p < 0.05$). The average VAS score among subjects upon termination of the game was higher in the neck than in the trunk.

Discussion

The present study examines changes in the angle of the neck and trunk and EMG activation of CES, UT, LT, and TES during smartphone use. The results of this study show that, as expected, neck and trunk flexion increase as the duration of smartphone use increases. In addition, the EMG amplitudes of the CES muscle group and the CES 10th %APDF values at 5–6 minutes, 10–11 minutes, and 15–16 minutes of smartphone use were also greater in comparison with these values at the start of smartphone use for the experiment herein. The EMG amplitude and 10th %APDF values of the TES and LT muscles of subjects, however, bilaterally decreased from their values at the start of smartphone use for the experiment herein.

The rate of neck flexion increase was very sharp among subjects as they played the smartphone game, and a significant increase in neck flexion began as early as 5 minutes after the start of smartphone use. Lee, Park, and Yoo (2011) reported that meaningful neck flexion increase began after 10 minutes of typing on a desktop computer while crossing legs. Even though the subjects in this study were not sitting with crossed legs, our subjects also showed gradual increase of neck flexion as the task time increased, and the timing of substantial neck flexion increase in this experiment occurred much earlier than in the findings of the work of Lee, Park, and Yoo (2011). In most cases of people typing on desktop and laptop computers, the computers are placed on a standard desk and the arms

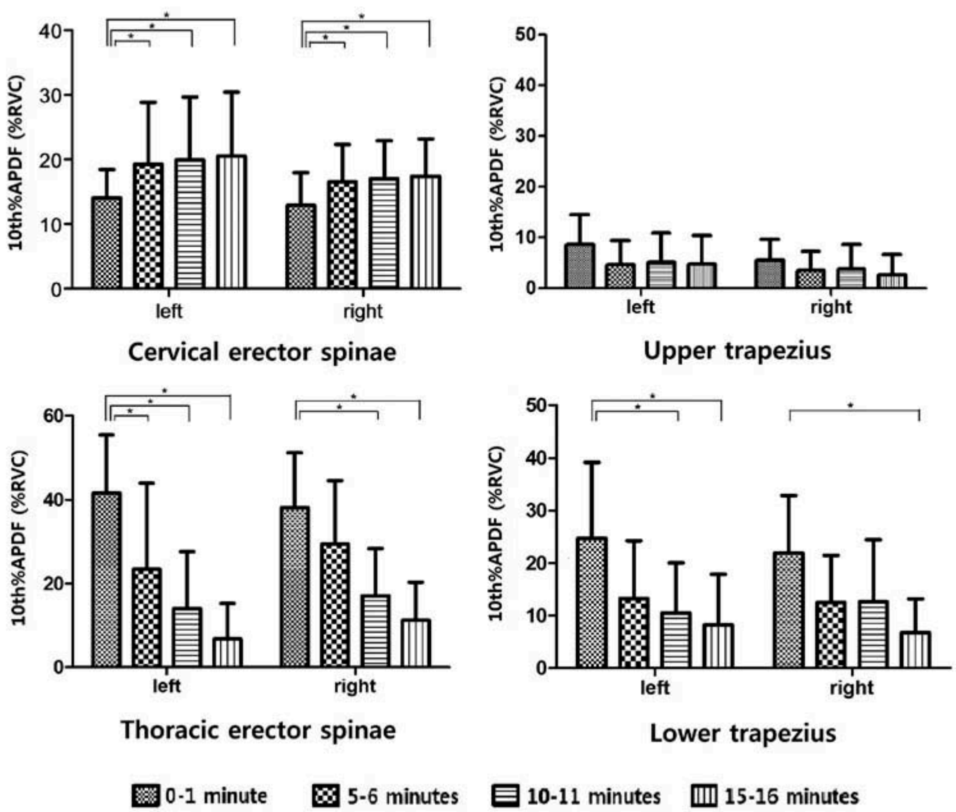

Figure 6. Comparison of mean 10th% amplitude probability distribution function (APDF) values of four muscle groups (i.e., the CES, UT, TES, and LT) (*$p < 0.05$). Error bars represent standard deviation. RVC: reference voluntary contraction.

of users are supported on the desk for typing. On the contrary, people often use smartphones with their arms in unsupported positions when sitting on the bus or subway. In this situation, the weight of unsupported arms, together with the weight of smartphone, conceivably pulls the shoulders of users downward. Thus, the height of a smartphone in use is relatively low, which is a position that people tend to bend their body toward the smartphone. In turn, this may increase the risk of neck and shoulder symptoms among smartphone users.

This study finds that the EMG amplitudes of the CES muscle group increased with a significant increase in neck flexion starting after 5 minutes of smartphone use. This result corresponds with the findings of Harms-Ringdahl et al. (1986), which assert that there is a high correlation between posture and muscle activity. Generally, it is explained that the reason for increased EMG activation is the generation of extensor moments against increased flexor moments associated with increased head and neck flexion during VDT-based tasks (Neumann, 2013). This study includes APDF analysis to ensure investigation of the transferring moment and load of muscle. In the CES muscle group, the APDF curve shifted to the right and the 10th %APDF value increased with increased duration of smartphone use. Higher APDF value and a shift to the right in the APDF curve represent muscle overloading (Hagberg, 1979; Jonsson, 1982; Jonsson, Persson, and Kilbom, 1988; Szeto, Straker, and O'Sullivan, 2009). Accordingly, this finding indirectly indicates increased mechanical load and fatigue in the CES muscle group as a result of smartphone use (Murata and Ishihara, 2005). Furthermore, continuously increased neck flexion posture, CES muscle load, and EMG activation during smartphone gaming might induce compression force on the cervical spine. Therefore, after only 16 minutes of smartphone use, the subjects herein experienced moderate neck pain (Harrison, Sinatra, Morgese, and Chung, 1988; Plancarte et al., 1997).

Szeto and Lee (2002) stated that trunk posture remains relatively upright in comparison with the neck posture during tasks at a desktop computer. In this study, however, trunk flexion as well as neck flexion increased with increased duration of smartphone use. Unexpectedly, in this study, TES EMG activation also decreased with the increased trunk flexion and time. As Callaghan and Dunk (2002) stated, the low EMG activation of the erector spinae muscle during flexed posture was associated with flexion relaxation phenomenon (FRP). In addition, the 10th %APDF value was lower in the flexed posture, which might be indirectly explained by transferring of the load from the muscle to the other structure while sustaining the flexed posture of the spine. This coincides with the hypothesis of FRP where low EMG activation was caused by transferring load from the muscle to the passive structures of the spine (Pialasse, Lafond, Cantin, and Descarreaux, 2010). These changes might be one reason for the lower back pain and degeneration (Mörl and Bradl, 2013). Thus, FRP during slouched posture can be problematic.

The UT works as a stabilizer to support their upper extremity during finger movement in unsupported posture. Therefore, the tone and EMG activity of the UT are expected to rise (Schleifer et al., 2008; Zetterberg, Forsman, and Richter, 2013). However, the UT EMG amplitude and 10th %APDF did not increase as the duration of smartphone use increased. This can be explained by the finding that the UT was first activated to maintain the neck and scapular positions and to withstand the weight of the arm and smartphone. However, as time progressed, it is assumed that the UT is passively stretched by the weight of the arm and smartphone (Sahrmann, 2002), resulting in decreased activity in this muscle. Therefore, the value of UT EMG activity and 10th %APDF was low in general, and significant increases in UT EMG and 10th %APDF were not found.

Our study has several limitations. First, the study includes only male participants, because cultural norms in Korea prohibit females from consenting to unclothed upper body photographs per the requirements of this study, and we have small sample size. Second, the cervical angle seems to be greater than that routinely measured at end-range of the cervical spine in a clinical setting. In such a setting, neutral head position was defined as 0 degrees. However, according to the angle described in the text, neutral position is never at 0 degrees, because we measured and defined the neck flexion angle as the angle between the line from the right tragus to the seventh cervical spinous process and the vertical axis that passes C7. Thus, the neck flexion angle should be carefully interpreted by clinicians. Furthermore, future studies with longitudinal experiments are suggested to examine the long-term influence of prolonged use of smartphones on the development of chronic forward neck posture and thoracic kyphosis among users. Finally, even though we selected the most frequently observed posture among ordinary healthy young males while they are texting or playing games on their smartphone, there is a limitation in generalizing the findings of this study to a person who uses their smartphone in a different posture, as the participants were not allowed to use the smartphone with their usual posture.

Conclusion

The present study examines the influence of smartphone use on pain, posture, and muscle activity in the cervical and thoracic regions. Smartphone use substantially induced more flexed posture on the neck and trunk and changed the muscle activation pattern of the neck and trunk extensors within a relatively short period of time, causing all participants to feel pain in the neck and trunk. Thus, clinicians should consider the influences of smartphone use on posture and muscle activity during evaluation, intervention, and prevention of neck and trunk conditions.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the article.

Funding

This work was supported by the National Research Foundation of Korea Grant, with funding by the Korean Government (NRF-2013S1A5B8A01055336).

References

Brandt LP, Andersen JH, Lassen CF, Kryger A, Overgaard E, Vilstrup I, Mikkelsen S 2004 Neck and shoulder symptoms and disorders among Danish computer workers. Scandinavian Journal of Work, Environment and Health 30: 399–409.

Burgess-Limerick R, Plooy A, Fraser K, Ankrum D 1999 The influence of computer monitor height on head and neck posture. International Journal of Industrial Ergonomics 23: 171–179.

Callaghan JP, Dunk NM 2002 Examination of the flexion relaxation phenomenon in erector spinae muscles during short duration slumped sitting. Clinical Biomechanics 17: 353–360.

Carter J, Banister E 1994 Musculoskeletal problems in VDT work: A review. Ergonomics 37: 1623–1648.

Criswell E 2010 Cram's Introduction to Surface Electromyography, (2nd ed). Jones & Bartlett Publishers. Sonoma State University, MA, United States.

Ellegast R, Hamburger R, Keller K, Krause F, Groenesteijn L, Vink P, Berger H 2007 Effects of using dynamic office chairs on posture and EMG in standardized office tasks. In: Dainoff MJ (Ed) Ergonomics and Health Aspects of Work with Computers. EHAWC 2007. Lecture Notes in Computer Science, vol 4566, 34–42. Berlin, Heidelberg Springer.

Fernandez-de-Las-Penas C, Alonso-Blanco C, Cuadrado M, Pareja J 2006 Forward head posture and neck mobility in chronic tension-type headache a blinded, controlled study. Cephalalgia 26: 314–319.

Fujimaki G, Mitsuya R 2002 Study of the seated posture for VDT work. Displays 23: 17–24.

Fujiwara K, Tomita H, Maeda K, Kunita K 2009 Effects of neck flexion on contingent negative variation and anticipatory postural control during arm movement while standing. Journal of Electromyography and Kinesiology 19: 113–121.

Gigante M, Sciascia G, Basso A, Lovreglio P, Russo A, De Frenza M, et al. 2004 Could VDT use induce thoracic hyperkyphosis? Preliminary data. Giornale Italiano di Medicina del Lavoro ed Ergonomia. 27:119–123.

Hagberg M 1979 The amplitude distribution of surface EMG in static and intermittent static muscular performance. European Journal of Applied Physiology and Occupational Physiology 40: 265–272.

Hansson GÅ, Nordander C, Asterland P, Ohlsson K, Strömberg U, Skerfving S, Rempel D 2000 Sensitivity of trapezius electromyography to differences between work tasks—Influence of gap definition and normalization methods. Journal of Electromyography and Kinesiology 10: 103–115.

Harms-Ringdahl K, Ekholm J, Schüldt K, Nemeth G, Arborelius UP 1986 Load moments and myoelectric activity when the cervical spine is held in full flexion and extension. Ergonomics 29: 1539–1552.

Harrison DM, Sinatra R, Morgese L, Chung JH 1988 Epidural narcotic and patient-controlled analgesia for post-cesarean section pain relief. Anesthesiology 68: 454–456.

Jensen C, Finsen L, Hansen K, Christensen H 1999 Upper trapezius muscle activity patterns during repetitive manual material handling and work with a computer mouse. Journal of Electromyography and Kinesiology 9: 317–325.

Jonsson BG 1982 Measurement and evaluation of local muscular strain in the shoulder during constrained work. Journal of Human Ergology 11: 73–88.

Jonsson BG, Persson J, Kilbom Å 1988 Disorders of the cervicobrachial region among female workers in the electronics industry: A two-year follow up. International Journal of Industrial Ergonomics 3: 1–12.

Kim T, Cho S, Shin H 2012 A comparison of trapezius muscle activity while performing a dictation task, sitting in an auditorium chair and a classroom chair. Physical Therapy Korea 19: 46–55.

Kim Y, Kang M, Kim W, 2013 Influence of the duration of smartphone usage on flexion angles of the cervical and lumbar spine and on reposition error in the cervical spine. Physical Therapy Korea 20: 10–17.

Lee J, Park S, Yoo W 2011 Changes in craniocervical and trunk flexion angles and gluteal pressure during VDT work with continuous cross-legged sitting. Journal of Occupational Health 53: 350–355.

Lin IM, Peper E 2009 Psychophysiological patterns during cell phone text messaging: A preliminary study. Applied Psychophysiology and Biofeedback 34: 53–57.

Marcus M, Gerr F, Monteilh C, Ortiz DJ, Gentry E, Cohen S, Edwards A, Ensor C, Kleinbaum D 2002 A prospective study of computer users: II. Postural risk factors for musculoskeletal symptoms and disorders. American Journal of Industrial Medicine 41: 236–249.

Merletti R, Parker PA 2004 Electromyography: Physiology, Engineering, and Non-Invasive Applications. John Wiley & Sons. Hoboken, NJ.

Mörl F, Bradl I 2013 Lumbar posture and muscular activity while sitting during office work. Journal of Electromyography and Kinesiology 23: 362–368.

Murata A, Ishihara H 2005 Evaluation of shoulder muscular fatigue induced during mouse operation in a VDT task. IEICE Transactions on Information and Systems 88: 223–229.

Neumann DA 2013 Kinesiology of the Musculoskeletal System: Foundations for Rehabilitation. Elsevier Health Sciences. Marquette University, Milwaukee, WI.

O'Sullivan PB, Grahamslaw KM, Kendell M, Lapenskie SC, Möller NE, Richards KV 2002 The effect of different standing and sitting postures on trunk muscle activity in a pain-free population. Spine 11: 1238–1244.

Park JH, Kang SY, Jeon HS 2013 The effect of using smartphones on neck and shoulder muscle activities and fatigue. Physical Therapy Korea 20: 19–26.

Park S, Yoo W 2012 Effect of EMG-based feedback on posture correction during computer operation. Journal of Occupational Health 54: 271–277.

Pialasse JP, Lafond D, Cantin V, Descarreaux M 2010 Load and speed effects on the cervical flexion relaxation phenomenon. BMC Musculoskeletal Disorders 11: 46.

Plancarte R, de Leon-Casasola OA, El-Helaly M, Allende S, Lema, MJ 1997 Neurolytic superior hypogastric plexus block for chronic pelvic pain associated with cancer. Regional Anesthesia and Pain Medicine 22: 562–568.

Sahrmann, S 2002 Diagnosis and treatment of movement impairment syndromes. Elsevier Health Sciences 219. St. Louis, MO.

Schleifer LM, Spalding TW, Kerick SE, Cram JR, Ley R, Hatfield BD 2008 Mental stress and trapezius muscle activation under psychomotor challenge: A focus on EMG gaps during computer work. Psychophysiology 45: 356–365.

Seghers J, Jochem A, Spaepen A 2003 Posture, muscle activity and muscle fatigue in prolonged VDT work at different screen height settings. Ergonomics 46: 714–730.

Smith A 2010 Mobile Access. Pew Research Center.

Smith A 2015 US Smartphone Use in 2015. Pew Research Center.

Spallek M, Kuhn W, Uibel S, van Mark A, Quarcoo D 2010 Work-related musculoskeletal disorders in the automotive industry due to repetitive work- implications for rehabilitation. Journal of Occupational Medicine and Toxicology 5: 5–6.

Straker L, Jones KJ, Miller J 1997 A comparison of the postures assumed when using laptop computers and desktop computers. Applied Ergonomics 28: 263–268.

Szeto GP, Lee R 2002 An ergonomic evaluation comparing desktop, notebook, and subnotebook computers. Archives of Physical Medicine and Rehabilitation 83: 527–532.

Szeto GP, Straker LM, O'Sullivan PB 2009 Examining the low, high and range measures of muscle activity amplitudes in symptomatic and asymptomatic computer users performing typing and mousing tasks. European Journal of Applied Physiology 106: 243–251.

Yoo WG, Kim MH 2010 Effect of different seat support characteristics on the neck and trunk muscles and forward head posture of visual display terminal workers. Work: A Journal of Prevention, Assessment and Rehabilitation 36: 3–8.

Zetterberg C, Forsman M, Richter H 2013 Effects of visually demanding near work on trapezius muscle activity. Journal of Electromyography and Kinesiology 23: 1190–1198.

Zhu X, Shin G 2012 Shoulder and neck muscle activities during typing with articulating forearm support at different heights. Ergonomics 55: 1412–1419.