Changes in Posture of the Upper Extremity Through the Use of Various Sizes of Tablets and Characters

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Abstract. The aim of this study was to analyze the posture of the upper extremities during the use of mobile communication devices. Using various sizes of mobile devices and display characters, we examined subjective muscular loads, viewing distances, and joint angles in the head, neck, shoulder, elbow, and lower back. No postural differences were found between the use of 7-in and 10-in devices, whereas the head and neck were significantly flexed and the elbow angles were decreased during the use of the 13-in device. Character size significantly affected the viewing distance; however, no differences in body angles were found. Participants continually increased their muscular loads during the task by flexing the head and neck, despite their high subjective discomfort levels in the neck and upper arm.

Keywords: tablet devices, smartphone syndrome, upper extremity posture, angle analysis.

1 Introduction

The use of small mobile communication devices equipped with touch panels has become common. The resulting increase in the incidence of musculoskeletal disorders (MSDs) caused by extensive use of these devices (e.g., text messaging and viewing Web pages) has become a major concern [1]. Previous studies on MSDs associated with the extensive use of mobile devices have focused on subjective muscle loads on the upper extremities [2] and on the movement of the thumb during device operation [3]. The posture assumed during mobile device use has been reported to result in tensing of the upper extremities, which can lead to the development of MSDs [4]. However, no reports have addressed how changes in upper extremity posture during the use of mobile devices may affect MSDs risk. Moreover, no objective data have been reported regarding the pathology of smartphone syndrome, caused by extensive use of mobile devices, in relation to the size of the mobile device [3]. Although studies [5] have reported that the size of the characters on the display screen affects readability, the effect of character size on upper extremity posture has not been addressed.

Establishing guidelines to prevent MSDs caused by extensive use of mobile devices is important. To begin the establishment of such guidelines, we considered it

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important to objectively assess the posture of the upper extremities during the use of devices with different sizes of characters and display areas. In this study, we report the changes in upper extremity posture depending on the size of the mobile device used and the size of the characters displayed on its screen.

2 Method

2.1 Participants

Ten right-handed university students who used mobile devices regularly (5 men and 5 women) participated in the experiment. Their corrected vision was greater than 20/30.

2.2 Experimental Apparatus

In this study, video images were obtained while the participant was operating the mobile device to observe whether the posture of the upper extremities changed during device use. A digital video camera (PJ760V, SONY) was used, and the frame rate of the video was set to 29 fps. Three mobile devices of different sizes (7-in TOSHIBA REGZA AT570, 10-in AT700, and 13-in AT830) were used (Figure 1). Their weights were 332 g, 535 g, and 1000 g, respectively.

Fig. 1. Mobile devices used in the experiment
(7 in, 10 in, and 13 in, from left to right)

2.3 Experimental Procedures

Colored markers (diameter, 50 mm) were attached to the bodies of the participants to assist in the measurement of dynamic angular changes in upper extremity posture. The markers were attached to the body at the canthus, tragus, C7 vertebra, acromion, elbow, and lower back and at the center of the device, as shown in Figure 2.

In this experiment, 3 character sizes (small, 1 × 1 mm; medium, 3 × 3 mm; and large, 5 × 5 mm) and 3 display sizes (7 in, 10 in, and 13 in) were chosen as independent variables, giving a total of 9 combinations. The order of the trials was randomized.

Fig. 2. Location of the markers

To become familiar with the operation of the mobile devices used in the experiment, participants underwent practice sessions before the experiment. The input method was set to flick motion. Participants were instructed to use the left hand for grasping the device and the right hand for character entry. At the start of the trial, participants were asked to perform a simple text-editing operation for 5 minutes. In addition, they were instructed orally to enter the text message as follows: "There is no need to try to enter as fast as you can. Please focus on the work on your own pace." After 5 minutes, the instructor gave a signal to stop. After each trial, the participants filled out a questionnaire regarding the subjective muscular loads during operation of the mobile device.

3 Data Analysis

3.1 Video Analysis of Dynamic Angular Changes in Body Position

Dynamic angular changes were determined using an image processor (Labview, National Instruments). A still image was extracted every 30 sec (from 0 sec to 300 sec) for further analysis. Image analysis techniques were used to obtain the angles of the head, neck, shoulder, elbow, and lower back and the viewing distance. Angles were estimated using the reference markers, following the regimen reported by Sommerich et al. [6].

3.2 Range of Motion

The range of motion in the upper extremities, especially the head and neck, vary widely among participants [7]. Therefore, even if the same angle was obtained for different participants, the absolute range of motion could differ between participants. In this study, we used percentage range of motion (%ROM) as an index for normalizing the magnitude of the angle to represent the level of body flexion for each participant. Therefore, we defined "zero position" as the neutral posture assumed when relaxed. The %ROM was calculated as the absolute range of motion divided into the direction of extension and flexion and normalized by the maximum angles, as shown in Figure 3.

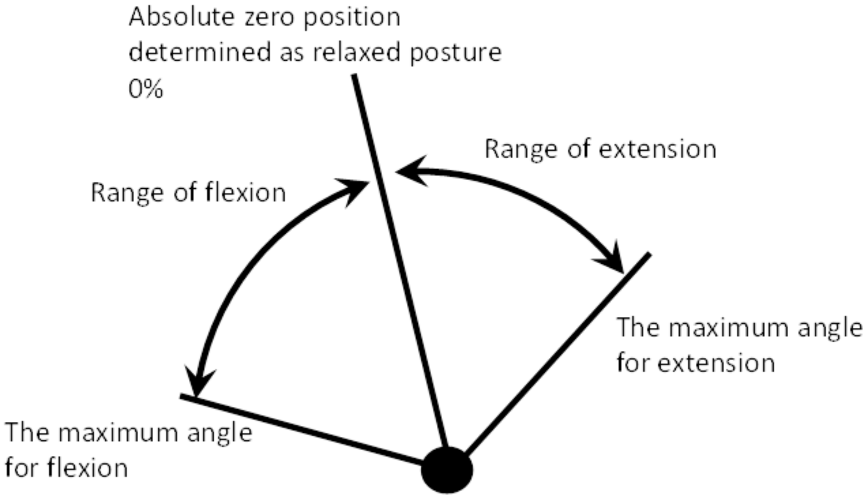

Fig. 3. Flexion and extension motions starting from a relaxed posture (absolute zero position)

3.3 Collecting and Analyzing Subjective Responses

Simultaneous with measurements of the upper extremity angle, the subjective discomfort level caused by the muscular load was assessed using the Borg Scale (CR-10). Subjective responses were recorded for eye fatigue and muscular loads of the upper back, neck, and upper left arm [3]. In addition, the participants were instructed to report any sense of muscular load in areas other than those about which we specifically inquired. For statistical analysis, ANOVA was used to analyze data on each body angle and viewing distance, as well as subjective responses, in relation to the independent variables of device and character size.

4 Results

4.1 Effect of Display Size on Upper Extremity Posture

The size of the mobile device was significantly associated with the viewing distance; flexion angles at the head, neck and elbow; and subjective muscular loads on the neck and left upper arm (Table 1). Multiple comparisons revealed that there were no significant differences between viewing distances for 7-in and 10-in devices. However, a significant difference was observed between the viewing distances for 13-in, 7-in, and 10-in devices. No significant difference was observed with respect to eye fatigue, the subjective muscular load on the upper back, or the flexion angle at the shoulder and lower back.

Table 1. Viewing distance, body angles, subjective muscular loads, and eye fatigue according to the size of the mobile device

＊＊; $p<0.01$

	7in	10in	13in	Significance
Viewing distance [mm]	252	251	328	**
Flexion at the head [%]	49%	48%	57%	**
Flexion at the neck [%]	38%	38%	52%	**
Flexion at the shoulder [%]	−1%	−3%	−3%	NS
Flexion at the elbow [%]	52%	53%	38%	**
Flexion at the lower back [%]	5%	4%	6%	NS
Subjective muscular load at the upper back [−]	3.63	3.83	4.27	NS
Subjective muscular load at the neck [−]	2.93	3.33	4.56	**
Subjective muscular load at the left upper arm [−]	3.67	4.33	5.41	**
Eye fatigue level [−]	2.36	2.33	2.73	NS

Table 2. Viewing distance, body angles, subjective muscular loads, and eye fatigue in relation to character size

＊＊; $p<0.01$

	small	mid	large	Significance
Viewing distance [mm]	258	284	288	**
Flexion at the head [%]	51%	52%	51%	NS
Flexion at the neck [%]	43%	44%	41%	NS
Flexion at the shoulder [%]	−2%	−2%	−2%	NS
Flexion at the elbow [%]	50%	47%	47%	NS
Flexion at the lower back [%]	5%	5%	5%	NS
Subjective muscular load at the upper back [−]	4.13	3.77	3.67	NS
Subjective muscular load at the neck [−]	3.89	3.56	3.37	NS
Subjective muscular load at the left upper arm [−]	4.78	4.48	4.15	NS
Eye fatigue level [−]	2.97	2.33	2.12	NS

A significant correlation was observed between viewing distance and character size. Multiple comparisons revealed significant differences in the viewing distance between the large (5 × 5) and small (1 × 1) character sizes and between the medium

(3 × 3) and small character sizes (1 × 1) (Table 2). No significant difference was found for any of the other variables.

4.2 Effect of Task Performance Time on Upper Extremity Posture

According to Lin et al. [4], people tend to unconsciously build up tension in the upper extremities, especially the neck and shoulders, during extensive operation of mobile communication devices. It is therefore likely that the posture of the upper extremities changes with the time of mobile device operation. To test this hypothesis, we compared the average flexion angles in each part of the upper extremities and the viewing distance after 30 and 300 sec of mobile device operation (Tables 3–5).

Table 3. Changes in flexion angles of the upper extremities and viewing distance with operation time of a 7-in mobile device

＊＊; $p<0.01$ ＊; $p<0.05$

	30[sec]	300[sec]	Significance
Viewing distance [mm]	258	239	**
Flexion at the head [%]	43%	50%	*
Flexion at the neck [%]	34%	40%	**
Flexion at the shoulder [%]	−2%	−2%	NS
Flexion at the elbow [%]	49%	52%	**
Flexion at the lower back [%]	3%	3%	NS

Table 4. Changes in flexion angles of the upper extremities and viewing distance with operation time of a 10-in mobile device

＊; $p<0.05$ †; $p<0.1$

	30[sec]	300[sec]	Significance
Viewing distance [mm]	258	245	†
Flexion at the head [%]	44%	49%	*
Flexion at the neck [%]	34%	35%	NS
Flexion at the shoulder [%]	−3%	−3%	NS
Flexion at the elbow [%]	49%	51%	NS
Flexion at the lower back [%]	6%	6%	NS

Table 5. Changes in flexion angles of the upper extremities and viewing distance with operation time of a 13-in mobile device

＊＊; $p<0.01$ ＊; $p<0.05$

	30[sec]	300[sec]	Significance
Viewing distance [mm]	282	346	*
Flexion at the head [%]	48%	67%	**
Flexion at the neck [%]	38%	61%	**
Flexion at the shoulder [%]	−1%	−3%	NS
Flexion at the elbow [%]	41%	26%	*
Flexion at the lower back [%]	4%	6%	*

The viewing distance significantly decreased and the flexion angles in the head, neck, and elbow significantly increased between 30 and 300 sec of mobile device operation (Table 3). The viewing distance decreased and the flexion angles in the head significantly increased between 30 and 300 sec of mobile device operation (Table 4). The viewing distance and the flexion angles in the head, neck, elbow, and lower back significantly increased between 30 to 300 sec of mobile device operation (Table 5). Therefore, the posture of the upper extremities changed with performance time; the flexion angles increased in the head, neck, and lower back and decreased in the elbow (with the viewing distance) for the 13-in device compared to the other devices.

5 Discussion

The viewing distance and the posture of the upper extremities changed with the size of the mobile device. A significant change was observed in the flexion angles of the head, neck, and elbow with the time of device operation of the 13-in device but not the 7- or 10-in device. In particular, a high subjective muscular load on the left arm was observed compared to the other parts of the body during operation of the 13-in device. This load may lead to the observed change in posture, most often the placement of the device on top of the thigh to support the weight of the device, causing hyperflexion of the head and neck. If the weight of the device exceeded the level that the participant could hold while in an upright position, they changed the viewing distance and hyperflexed the head and neck. While the participants strongly felt that the subjective muscular load on the neck increased with increasing size of the mobile device, they tended to continue flexing the head and neck, with more neck flexion over time. A previous anatomical study [7] reported that flexing the head and neck affects hypertension of the trapezius, located in the upper back. However, no significant differences in the subjective muscular load in the upper back were observed, although the flexion angles of the head and neck significantly increased with increase in size of the mobile device. This observation is consistent with the report by Berolo et al. [2], suggesting that the subjective muscular load on the upper back does not necessarily lead to hypertonus of the trapezius from flexion of the head and neck.

Increasing the character size did not appear to change the angle of any part of the upper extremity, although the viewing distance increased. This observation suggests that the whole upper body cooperatively adjusted to decrease the viewing distance, not just one isolated part of the body. Enlarging the text on the mobile device actually produced a change in the posture of the upper extremities. A comparison of differences in muscle strength and stature of participants is required to clarify whether text enlargement effectively reduces the risk of MSDs.

In this study, we observed that the flexion angles of the head and the viewing distance changed significantly with the time of mobile device operation. Lin et al. [4] reported that muscle activity in the upper extremities changes under different working conditions (e.g., before work, during the first work break, during the second work break, and after work); however, studies regarding dynamic changes in posture during work have not been reported thus far. In our study, the flexion angle of the head increased with increasing time of mobile device operation. This observation indicates that the upper extremities remained tense throughout the task. Additional and more quantitative evaluation is therefore possible by studying the effect of muscular loads induced by different continual operation. Such information may help to clarify the relationship between mobile device use and the risk of developing MSDs.

6 Conclusion

This study aimed to determine whether changes in posture during mobile device use are related to the size of characters displayed on the screen or the mobile device size. No postural differences were found between the use of 7-in and 10-in devices, whereas the head and neck were significantly flexed and the elbow angles were decreased during the use of the 13-in device. We observed a tendency to support the subjective muscular load on the arm by resting the mobile device on the thigh. Character size did not affect posture but significantly affected the viewing distance; however, no differences were found in the body angles. Tension in the upper body increased with operation time of the mobile device; thus, operation of such devices for continuous stretches of time without breaks may be related to the risk of developing MSDs. Further research should focus on relating quantitative muscular loads recorded by electromyography to postural changes associated with the operation time of mobile devices.

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References

1. Judith, G., Driban, J., Thomas, N., Chakravarty, T., Channell, S., Komaroff, E.: Postures, typing strategies, and gender differences in mobile device usage: An observational study. Applied Ergonomics 43, 408–412 (2012)
2. Berolo, S., Wells, R.P., Amick, B.C.: Musculoskeletal symptoms among mobile hand-held device users and their relationship to device use: A preliminary study in a Canadian university population. Applied Ergonomics 42, 371–378 (2011)
3. Gustafsson, E., Johnson, P.W., Hagberg, M.: Thumb postures and physical loads during mobile phone use - A comparison of young adults with and without musculoskeletal symptoms. Journal of Electromyography and Kinesiology 20, 127–135 (2010)
4. Lin, I.-M., Peper, E.: Psychophysiological patterns during cell phone text messaging: A Preliminary Study. Applied Psychophysiology and Biofeedback 34, 53–57 (2009)
5. Kubota, S.: Effects of character size, character format, and pixel density on subjective legibility of reflective liquid crystal displays for personal digital assistants. The Institute of Image Information and Television Engineers 55(10), 1363–1366 (2001)
6. Sommerich, C., Starr, H., Smith, C., Shivers, C.: Effects of notebook, computer configuration and task on user biomechanics, productivity, and comfort. International Journal of Industrial Ergonomics 30, 7–31 (2002)
7. Donald, N., Hirata, T., Hirata, S.: Kinesiology of the Musculoskeletal System Foundations for Physical Rehabilitation. Ishiyaku Shuppan Kabushikigaisha, 128–360 (2008) (in Japanese)