Influence of posture awareness signals to the upper extremity posture and muscular loads during mobile device use

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The objective of this study was to evaluate the effectiveness of the awareness prompting in terms of readjustment of awkward posture and exceeding the muscular activities of the upper extremities when posture is worsened during the use of mobile devices. Viewing distance and flexion angles of the upper extremities (head, neck, elbow, and trunk) were estimated by using the images obtained by videotaping during the performance. Muscular activities of the upper extremities (trapezius, upper trapezius, and erector spinae) were calculated by using the surface electromyography during the performance. The results showed that viewing distance was decreased with the increase in the time of the task. However, it increased instantly after the awareness signal was given. The posture of the upper extremities showed similar trends; that is, the posture worsened along with the mobile device use and showed changes in posture to a sudden upright position after the presentation of the awareness signal. Viewing distances and elbow postures worsened again as time elapsed. No significant differences in muscular activities of the upper extremities were found between before and after the warning signals. These results suggest that unhealthy postures of the upper extremities were improved temporarily by the awareness given to mobile device users once in the middle of the performance. These improved postures, however, did not continue after the warning. An effective warning protocol should be further developed in order to secure the low risk of inducing the visual strain and the reduced static muscular loads of the upper extremities.

Practitioner Summary: The purpose of this study was to examine the effect of warning awareness in terms of sustaining appropriate posture and the muscular activities of the upper extremities. The results suggest that unhealthy postures of the upper extremities were improved temporally by the awareness presentation once in the middle of the performance. These improved postures, however, did not continue after the warning.

Keywords: musculoskeletal disorders, mobile device, posture, muscular activity, warning

1. Introduction

Incident cases of musculoskeletal disorders (MSDs) caused by intensive use of mobile devices has increased with dramatic spread of mobile devices equipped with touch displays such as smartphones and tablet computers in recent years (Judith et al. 2012). We have been conducting an evaluation of the damaging effect of using mobile devices equipped with touch displays on the musculoskeletal systems. Results of our previous study indicated that mobile device users tended to have awkward postures while using mobile devices, resulting in unhealthy conditions, with excessive physical loads to the upper extremities (Maniwa et al. 2013). A major cause of the incidence of MSDs is reportedly sustained unhealthy posture of the upper extremities (Asundi et al. 2012). Previous studies suggested approaches to reduce the potential risk of MSDs, where they developed the warning system to provide awareness to the mobile device users (Lee et al. 2013; Khurana et al. 2014).

However, information is lacking on whether the risk of MSDs can be reduced by the awareness given to mobile device users. Thus, whether the awareness given to mobile device users effectively minimized the risk of MSDs remains unclear.

Therefore, the objective of this study was to evaluate the effectiveness of providing awareness regarding the appropriate and muscular activity of the upper extremities during mobile device use.
2. Methods

2.1 Subjects

We conducted a laboratory study with five right-handed male subjects aged 20 to 22 years. The subjects regularly used mobile devices equipped with touch displays. Their corrected visions were greater than 20/30.

2.2 Good and bad postures

We defined good posture as posture requiring minimum antigravity muscular contractions and energy consumption for supporting the body (Seki et al. 1990). The posture was anatomically determined such that the center-of-gravity line of the body went through the tragus, acromion, and greater trochanter, as shown in Figure 1 (Nakamura et al. 2002).

We defined bad posture as posture requiring excessive energy consumptions due to unnecessary muscular contractions (Seki et al. 1990). An example of bad posture is to bend over with the head leaning forward, as shown in Figure 1 (Nakamura et al. 2002).

2.3 Experimental apparatus

The subjects were videotaped throughout the performance in order to clarify the changes in posture angles of the upper extremities after awareness was given to the subjects. A video camera (HDR-SR1, Sony) was used, and the frame rate of the video camera was set to 29 fps. The illumination environment in the laboratory was 140 lx. Indirect lightning was applied to prevent glare. The mobile device equipped with a touch display (EVO 3D ISW12HT, HTC, 4 in, 171 g) was used, as shown in Figure 2. The character size on the display was set to 16 px.

We set up the software system equipped with mobile devices such that awareness was given to the subjects in order to continually remind them of unhealthy posture at the upper extremities. The system was designed to start along with the activation of the mobile device, and the warnings were presented on the display of the mobile devices for 4 seconds in the middle of the task and the presented warnings were vanished automatically.

2.4 Experimental setups

Colored markers (50 mm in diameter) were attached to the bodies of the subjects in order to analyze changes in posture angles of the upper extremities during the performance. The markers were attached to the canthus, tragus, C7 vertebra, acromion, elbow, greater trochanter, and center of the device, as shown in Figure 3.
Electrodes of surface electromyography (EMG; BA-U410, NIHONSANTEKU) along with reference electrode (M-150, NIHON KOUDEN) were attached to the bodies of the subjects in order to obtain muscular activities of the upper extremities during the performance. The surface EMG electrodes were attached to the left hand neck trapezius, upper trapezius, and erector spinae, and the reference electrode was attached to the clavicle, as shown in Figure 4. The reason for selecting the muscles in the left hand was that the static load of their upper left arm was more severe than that of their upper right arm when gripping a mobile device equipped with touch displays (Maniwa et al. 2013). EMG signals were recorded during the performance. The sampling frequency was set to 1000 Hz. Amplifier (AP1132, NIHONSANTEKU) and data sampling software (AP Monitor, NIHONSANTEKU) were used for the EMG recording as well.
2.5 Experimental procedures

Experimental procedures were developed as follows:

1. The outline of the experimental procedure was described to subjects before the experiments. Flick motions were chosen as the input method. The subjects were instructed to use the left hand for gripping the mobile device equipped with touch display and the right hand for entering the characters.

2. The subjects were also instructed to follow the instructions of the presented warning signals during the performance.

3. At the start of the trial, the subjects were asked to perform a text-editing task for 5 minutes. After 5 minutes, the instructor signaled to the subjects to stop the task.

4. After each trial, the subjects filled out a questionnaire regarding the subjects’ eye fatigue, muscular load, and effects of the warning signals on their operability.

3. Data Analysis

3.1 Posture angles of the upper extremities

Changes in posture angles of the upper extremities during the performance were analyzed by using the LabVIEW image processing software (National Instrument). The videotaped images were extracted every 5 sec from 0 to 300 sec for further analysis. The extracted images were used to obtain the angles of the head, neck, elbow, trunk and viewing distances. The angles and distances were estimated by using the colored reference markers (Sommerich et al. 2002; Maruta et al. 2006).

Percentage range of motion (%ROM) was used as an index of normalized magnitude of the joint angles in each subject. Thus, we defined neutral posture (good posture) as 0% flexion angle and 100% maximum flexion angle, as shown in Figure 5. %ROM can be calculated by using equation (1).

3.2 Muscular activities of the upper extremities

Muscular activities of the upper extremities during the performance were analyzed by using the data processing software (LabVIEW). For the analysis of EMG data, band-pass filtering between 5 and 300 Hz was used, followed by root mean square processing (Gustafsson et al. 2010).

The percentage of reference voluntary contraction (%RVC, led to equation (2)) was used as an index of normalizing magnitude of the muscular activities of each subject. The reference muscular activity was 1 kg, as in the study by Hansson et al. (2000).
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%ROM = Actual flexion angle – Neutral angle
Maximum flexion angle – Neutral angle

%RVC = Actual muscular activity - Minimum muscular activity
Reference muscular activity - Minimum muscular activity

4. Results and Discussions

4.1 Effect of awareness signal on viewing distance

The average change in viewing distance at each task time is shown in Figure 6. The awareness signal was given to the subjects at 150 sec after the task began. The results of the analysis of variance (ANOVA) showed that significant differences in viewing distance according to the time the task was performed. The results of multiple comparisons revealed that viewing distance at the beginning of the task was 265 mm, became shorter as time elapsed, approaching to 210 mm (p < 0.01), and returned back to 261 mm right after the awareness warning (p < 0.05). When approaching the end of the task, the viewing distance was shortened again, nearly at the level before the onset of the warning (224 mm; p < 0.1).

Our results suggest that the behavioral characteristics of mobile device users may be affected by the relationship between the timing of the task and the viewing distance. People tend to expect results within 60 sec after performing the trigger (Sugiyama 2005). According to the results of the questionnaires, two subjects responded that it was difficult to see and enter the characters to be shown on the display when they were further away from the display. Three subjects responded that they did not feel inconvenience when they were further away from the display: however, the results of temporal changes in viewing distance indicated that viewing distance tended to be decreased gradually in contradiction to their subjective responses. Thus, we suggest that mobile device users tend to prioritize the visibility and ease of character entry consciously or unconsciously over sacrificing their viewing distance, regardless of their awareness of their unhealthy posture.
4.2 Effect of awareness signal on posture angles of the upper extremities

The average change in posture of the upper extremities at each task time is shown in Figures 7 and 8. The results of the ANOVA showed significant differences in the posture of the upper extremities according to timing of the task. The results of multiple comparisons indicated that the elbow and head were significantly flexed with time elapsed from the beginning of the task. The head and trunk were significantly extended, and the neck and elbow tended to significantly extend between after the warning, respectively. The elbow tended to be flexed significantly with time elapsed from the onset of the warning.

These results could be explained by the habit of individuals. Unhealthy postures such as a rounded back were typical personal habits (Nakamura et al. 2002). It is important to point out such habit-like behaviors once it was observed by other people for the purpose of effective correction (Kikukawa et al. 2012). Therefore, redesigning the effective warning methods are necessary, where repetitive warning presentation for prompting postural changes should be applied, for reducing the potential risk of MSDs.
4.3 Effect of awareness signal on muscular activities of the upper extremities

The average change in muscular activities of the upper extremities at each task time is shown in Figure 9. The values shown in the figure were calculated by referring to the previous study (Rudroff et al. 2010). The results of the ANOVA revealed no significant differences in the muscular activities of the upper extremities.

Therefore, the muscular loads of the mobile device users were not decreased with the use of the proposed warning methods that was designed in this laboratory study. We conclude that redesigning the effective warning methods for reducing static muscular loads of the upper extremities is necessary.
5. Conclusions

The aim of this study was to examine the effect of posture and muscular activity of the upper extremities when awareness was given to the mobile device users at one time. The results showed that the decreased viewing distance and unhealthy posture of the upper extremities were improved temporarily by the awareness given to mobile device users in the middle of the performance. These improved viewing distance and postures, however, did not continue very well after the warning.

We suggest that these results were due to the habit and behavioral characteristics of the individual subject. In particular, the mobile device users tended to prioritize the productivity for optimizing the visibility and usability of entering characters over sacrificing the other properties such as decreasing the viewing distance and unhealthy posture of the upper extremity. The effective warning method, expressed by repetitive warning presentation for prompting postural changes from unconscious habit-like postures, for reducing the potential risk of MSDs should be further developed in order to reduce static muscular loads of the upper extremity.

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References


