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Neck kinematics and muscle activity during mobile device operations

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ABSTRACT

Neck pain is a significant health problem due to its high incident rates and economic costs. Increased use of touch screen mobile devices is becoming pervasive in the modern society and may further influence this already prevalent health problem. However, our current understanding of the cervical spine biomechanics during the operation of touch screen mobile devices is very limited. This study evaluated the neck extensor muscle activities and the kinematics of the cervical spine during the operation of a touch screen tablet and a smart phone. Three-variables, DEVICE, LOCATION and TASK were treated as the independent variables. NASA TLX revealed that "Gaming" was the least difficult task and "Typing" was the most difficult task. Participants of this study maintained significantly deeper neck flexion when operating a smart phone (44.7°), with the mobile devices set on a table (46.4°), and while performing a "Typing" task (45.6°). Lower levels of neck muscle activities were observed while performing a "Reading" task and holding mobile devices with hand. Lower levels of neck muscle activities were also observed when using a smart phone vs. a tablet, however such change was statistically insignificant.

Relevance to industry: The current study demonstrated that users maintain deep neck flexion when using touchscreen mobile devices. In the recent years, there is an increasing popularity of mobile smart devices in various occupational environments. The findings of this study may be useful in implementing human-centered task designs to reduce neck injury risks among mobile device users.

1. Introduction

In industrialized countries, neck pain is a significant musculoskeletal disorder (MSD) with high medical costs, social costs (Borghouts et al., 1999) and low rate of complete recovery (Cote et al., 2004). Previous studies have discovered high prevalence of neck pain among the general population (Makela et al., 1991; Bovim et al., 1994; Croft et al., 2001; Sim et al., 2006) and among computer users (Kamwendo et al., 1991; Chiu et al., 2002; Eltayeb et al., 2009). Neck pain reduces one's neck rotation range of motion and alters neck muscle activation patterns (Johnston et al., 2008). The impairment of neck muscle motor performance caused by neck pain could also decrease the stability of the cervical spine (Lindstrøm et al., 2011).

Previously, a number of risk factors that could contribute to the occurrence of neck pain have been identified. These risk factors can be generally categorized as individual factors, work-related factors and psychosocial factors. The major individual risk factors that are associated with neck pain are gender and previous history of neck complaints. Epidemiological studies discovered that females have significantly higher incidence rates of neck pain than males (Brandt et al., 2004; Andersen et al., 2008). History of neck pain is another predictive individual factor for neck pain. Studies have shown that neck pain is more likely to occur among individuals that have experienced it before (Jensen, 2003; Eltayeb et al., 2009). The association between work-related factors and neck pain has also been investigated (Ariëns et al., 2000). Previous studies concluded that prolonged neck flexion is highly associated with neck pain both among the general population (Sim et al., 2006) and among the office workers that use computers (Yu and Wong, 1996; Cagnie et al., 2007; Ming et al., 2004). *In-vitro* study suggested that human neck is more vulnerable in forward flexed postures than in upright neutral postures (Przybyla et al., 2007). Poor workstation design (e.g. the location of keyboard and mouse, height of

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computer screen) is another work-related factor that is significantly associated with the increase of neck pain (Sillanpaa et al., 2003; Korhonen et al., 2003). Previous studies have also discovered that psychosocial factors such as increase of task difficulty, psychological stress, and lack of social support could increase the risk of neck pain (Ariëns et al., 2001; Eltayeb et al., 2009; Hush et al., 2009; Nimbarte et al., 2012).

More recently, with the increasing use of portable handheld electronic devices such as touch screen tablets and smart phones, concerns are raised regarding the poor neck posture that users may employ and its potentials of causing neck and shoulder strain. One observational study showed that the majority of users maintained flexed neck postures during the use of mobile devices (Gold et al., 2012). A recent study identified neck pain as the most severe MSD problem among mobile handheld device users (Berolo et al., 2011). Two other recent studies have investigated the influence of different device setups on wrist, shoulder and neck postures during the use of tablet computers (Young et al., 2012, 2013). However there is still a lack of research that has quantitatively investigated the neck postures and neck muscle activities during the use of different mobile devices with various screen sizes. Therefore, the purpose of this study was to evaluate the neck muscle activation levels and kinematics of the cervical spine during the use of touch screen mobile devices. Among the three categories of previously identified risk factors, the current study focused on the evaluation of work-related factors. The hypotheses of the current study were: (1) users will maintain deeper neck flexion postures and higher neck muscle activation levels when using mobile devices with smaller screen sizes; (2) more difficult tasks will result in deeper neck flexion postures and higher neck muscle activities.

2. Method

2.1. Participants

A total of fourteen right-handed participants (10 males and 4 females) were recruited for data collection in this study. All the participants were free from any type of MSDs and had no history of neck injury or notable neck pain. Before data collection, the experimental procedures were explained to the participants, and their signatures were obtained on informed consent forms which were approved by the local Institutional Review Board.

2.2. Apparatus

2.2.1. Data collection apparatus

A wireless surface electromyography (EMG) system (Telemyo 2400T, Noraxon Inc., AZ, USA) was used to collect neck muscle activities. Disposable, self-adhesive Ag/AgCl snap electrodes were used for the signal collection. The bipolar electrodes were pregelled with 1 cm in diameter and an inter-electrode distance of 2 cm. The frequency of EMG data acquisition was set at 1024 Hz.

The cervical spine kinematics data were recorded using Functional Assessment of Biomechanics (FAB) (BIOSYN, Canada) system. This full body 3D kinematic system consists of 13 small, lightweight sensors (4 × 7 × 2.4 cm) that attach to the selected body areas of the user. Each sensor has a triad of accelerometer, gyrometer, and magnetometer that allows real-time detection of angular displacement within biomechanical bodies. This is a completely wireless system and the posture data were acquired at a frequency of 100 Hz.

2.2.2. Handheld mobile devices

An iPhone (4th generation, Apple, California, USA) was used in the current study to represent a touch screen smart phone. The screen size of the iPhone is 115.2 mm H × 58.6 mm W × 9.3 mm D, and the total weight is 140 g. An iPad (2nd generation, Apple, California, USA) was used to represent a touch screen tablet. The screen size of the iPad is 241 mm H × 186 mm W × 8.6 mm D and the total weight is 601 g. The font sizes of both devices were set to system default.

2.3. Experimental design

A three-variable full factorial experimental design was employed in the current study. The first independent variable is DEVICE, two different mobile devices were tested in the current study and they were: a touch screen smart phone (i.e. iPhone) and a touch screen tablet (i.e. iPad). The second independent variable was the LOCATION that these mobile devices were used, there were two conditions. In the first condition mobile devices were placed on a flat table surface adjusted to the elbow height of testing participants (referred to as the "table" condition). In the second condition, participants were required to hold the device using his/her left hand during the operation (referred to as the "handheld" condition). The third independent variable was the TASK that participants were required to perform. Three different tasks were selected and they were referred to as "Reading", "Typing", and "Gaming" tasks. During the "Reading" task, participants were required to read a short paragraph of verbal material using the iBook application in the iPhone/iPad. The "Typing" task involved the use of the touch screen keyboard to re-type a message that was demonstrated on the same screen of that mobile device. For the "Gaming" task, participants played the gaming application "Fruit Ninja". This is a generic gaming application, and it is primarily played using the right forefinger; it involves minimum tilting and twisting of the handheld device (Fig. 1(a)–(d)). Three dependent variables considered in the current study were the neck flexion angle, EMG activity at the left side of the cervical extensor muscle and EMG activity at the right side of the cervical extensor muscle.

2.4. Protocol

Before the experiment started, the details of data collection procedures and specific requirements of the experimental tasks were introduced to each participant. To record the surface EMG data, the skin over the anatomical landmarks was shaved (if needed), abraded, and cleaned with 70% alcohol, prior to the placement of the EMG electrodes. EMG data were recorded from the cervical extensor (CE) muscles by placing two pairs of electrodes bilaterally at the C4 level (Fig. 1(e)). The electrodes were placed slightly inclined (approximately 35°) about 3 cm away from the vertical line of cervical vertebras (Nimbarte et al., 2010). Postural data was recorded by using three FAB motion sensors. The pelvic sensor was mounted at the L5/S1 level. The trunk sensor was mounted at the T10/T11 level. The head sensor was mounted at about the occipital region. Once mounted with the EMG electrodes and FAB motion sensors, participants were secured in a custom made chair with their head flexed 40° forward and performed maximum isometric head extension motion against a constant resistance. During the maximal voluntary contraction (MVC) the neck extensor muscle EMG signals were recorded. Next, the FAB system was calibrated. The calibration process is explained elsewhere (Nimbarte et al., 2013).

Upon finishing the calibration, the participants were trained for approximately 10 min to allow them get familiar with the mobile devices and the tasks they were required to perform. Subsequently, the participants performed three repetitions for each of the 12 different conditions (2 DEVICE × 2 LOCATION × 3 TASK) in a completely randomized order. The duration of each task was