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# Armrests and back support reduced biomechanical loading in the neck and upper extremities during mobile phone use

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ABSTRACT

Mobile phone use is known to be associated with musculoskeletal pain in the neck and upper extremities because of related physical risk factors, including awkward postures. A chair that provides adequate support (armrests and back support) may reduce biomechanical loading in the neck and shoulder regions. Therefore, we conducted a repeated-measures laboratory study with 20 participants (23 ± 1.9 years; 10 males) to determine whether armrests and back support during mobile phone use reduced head/neck flexion, gravitational moment, and muscle activity in the neck and shoulder regions. The results showed that the chair support (armrests and back support) reduced head/neck flexion ($p < 0.001$), gravitational moment ($p < 0.001$), and muscle activity ($p < 0.01$) in the neck and shoulder regions significantly compared to no chair support. These results indicate that a chair with adequate support can be an effective intervention to reduce the biomechanical exposures and associated muscular pain in the neck and shoulders during mobile phone use.

## 1. Introduction

Because of the rapidly-developing technology and various useful features of mobile phones, more people use them for longer periods on a daily basis (Ko et al., 2016; Shan et al., 2013). Approximately 77% of the U.S. population uses mobile phones (Smith, 2017; Gold et al., 2012) for an average of 3–4 h per day (Lipsman, 2017).

Despite the benefits of mobile phones, their use can increase risks of musculoskeletal pain and injuries, especially in the neck and upper extremities (Gustafsson et al., 2010; Kim, 2015; Xie et al., 2016). Head and neck postures play a vital role in cervical spine stress and associated neck pain (Lee et al., 2015b; Straker et al., 2009). A previous study demonstrated a positive relation between neck flexion and force acting on the neck; neck stress increased from approximately 5 kg (no flexion) to 27 kg (at 60° neck flexion) (Hansraj, 2014). Previous studies have shown that mobile phone use is associated with prolonged neck flexion (Guan et al., 2016; Vate-U-Lan, 2015) and therefore can increase a risk of neck pain (Kim and Koo, 2016; Lee et al., 2015a; b; Ning et al., 2015).

Further, mobile phone use can produce musculoskeletal pain in the upper extremities. Previous studies have shown that mobile phone use is associated with repetitive movements and awkward postures of the fingers and wrist (Gilman et al., 2015; Gustafsson et al., 2017, 2010; Lee et al., 2015b; Xiong and Muraki, 2014). As repetitive movements and awkward postures are physical risk factors for musculoskeletal fatigue and pain known well (da Costa and Vieira, 2010; Gallagher and Heberger, 2013), mobile phone use can increase a risk of developing musculoskeletal pain in the wrist and fingers.

Previous studies in conventional computer settings with keyboards and mice have shown that these awkward postures and related musculoskeletal pain in the upper extremities and neck can be reduced significantly by adjusting the display location and providing adequate arm and wrist supports (Onyebeke et al., 2014; Visser et al., 2000; Zhu and Shin, 2012). For example, having a screen at eye level reduces neck flexion, but at the expense of increased muscular loading in the shoulder/upper extremity regions (Straker and Mekhora, 2000). To avoid this trade-off, armrests would be useful to alleviate physical demands on the shoulders/upper extremities.

Such ergonomic interventions used in conventional computer settings can reduce awkward head/neck postures and associated musculoskeletal pain during prolonged mobile phone use effectively. However, little research has evaluated systematically the efficacy of adequate ergonomic controls to reduce biomechanical exposures during seated mobile phone use. Therefore, the goals of this study were two-fold: 1) to quantify the kinematics of the head/neck, gravitational moment, and muscle activity in the neck during mobile phone use objectively, and 2) evaluate the effects of armrests and back support on the biomechanical measures aforementioned.

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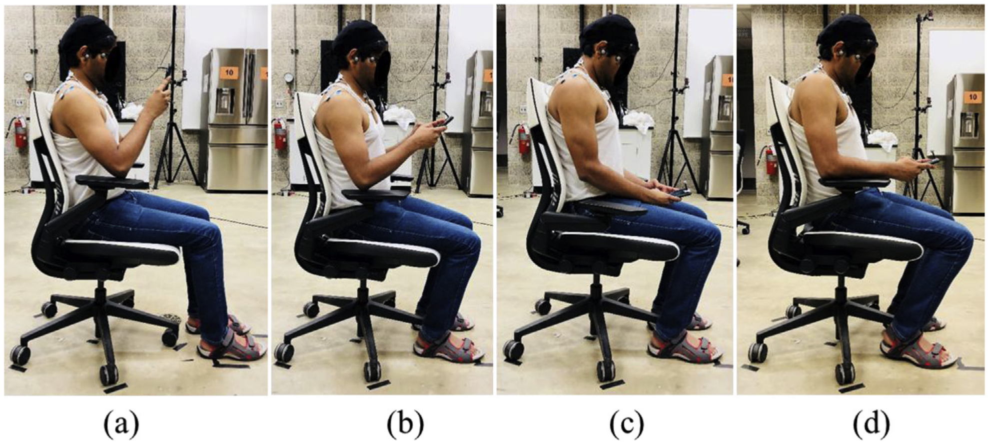


**Fig. 1.** Experimental setup with the chair support. (a) eye level, (b) chest level, (c) lap level, and (d) self-selected level.

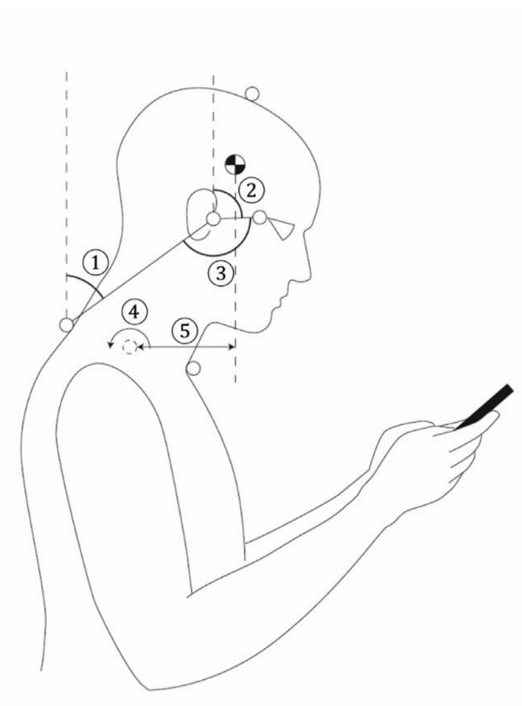


**Fig. 2.** Illustration of motion capture based dependent variables. ①: neck flexion angle, ②: head flexion angle, ③: cranio-cervical angle, ④: gravitational moment on the neck, and ⑤: gravitational moment-arm on the neck. Solid circle: reflective markers, and dotted circle: virtual marker.

To achieve our study goals, we tested two primary hypotheses: 1) The gravitational moment of the neck increases as the vertical location of a mobile phone lowers (from eye to lap level: Fig. 1) and 2) Armrests and back support during mobile phone use reduce the muscle activity in the neck and shoulder regions. This study result can be used to develop evidence-based ergonomic recommendations to reduce a risk of musculoskeletal pain in the neck and upper extremities during mobile phone use.

## 2. Methods

### 2.1. Participants

Twenty young adult participants (Average age: 23 ± 1.9 years old) with an equal sex distribution were recruited through e-mail solicitations in a university community. All participants were experienced mobile phone users (average mobile phone use experience: 6.6 ± 1.9 years) without current (past 7 days) musculoskeletal pain and a history of musculoskeletal disorders in the neck and upper extremities. A University's Institutional Review Board approved our experimental protocol and all participants gave written consent before participating in this study.

### 2.2. Experimental protocol

In a repeated-measures laboratory experiment, 20 participants were asked to use their own mobile phones under eight different experimental conditions (4 different mobile phone positions and 2 different chair supports). Four phone locations included eye, chest, lap, and a self-selected position, and two different chair support conditions included support (armrests and back support) and no support (Fig. 1). Participants self-selected the gaze distance (between the eyes and mobile phone) for each condition (eye: 26–29 cm; chest: 30–33 cm; lap: 47–53 cm; self-selected: 39–43 cm). For the self-selected position, participants were allowed to choose their preferred mobile phone positions with and without chair supports, respectively. The presentation order of the 8 experimental conditions was randomized and counterbalanced to minimize potential systematic biases.

Prior to the experiment, the chair height was adjusted according to ANSI/HFES standards (2007). Briefly, the chair height was adjusted to allow participants' feet to relax on the ground with their thighs parallel to the floor. During each task, participants were asked to accept a series of standardized, general open-ended questions from a researcher and answer them via text messages for 5 min using their phones. Five-minute breaks were given between the texting sessions to minimize residual fatigue effects of a previous session.

#### 2.2.1. Kinematic data

During the texting sessions, kinematic data from the head and neck were sampled at 100 Hz using an 8-camera optical motion capture system (Flex 13; Optitrack; Natural Point, OR) with reflective markers. Using double-sided tape, 9 14-mm reflective markers (M4, Optitrack) were attached bilaterally on the canthus, tragus, C7 spinous process, sternal notch, vertex of the head, and top and bottom of a mobile phone (Fig. 1). Raw kinematic data were filtered by a digital zero-phase 4th-order Butterworth filter with a cutoff frequency of 6 Hz (Motive, Optitrack). Using a custom-built Matlab program (R2015a, The MathWorks, Natick, MA), the head, neck, and cranio-cervical angle, gravitational moment, and gravitational moment-arms on the neck (Fig. 2) were calculated according to the methods recommended in previous studies (Vasavada et al., 2015; Young et al., 2012). The neck flexion angle was measured between the vertical line and the line from the mid-tragus (midpoint of the left and right tragus markers) to the C7 spinous