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The influence of a semi-reclined seated posture on head and neck kinematics and muscle activity while reading a tablet computer

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ABSTRACT

Increased tablet computer usage calls for a proper understanding of potential injury risks from these devices. The purpose of this study was to assess the influence of tablet computer reading postures on head and neck flexion and muscle activity. Nineteen participants completed read a tablet computer in four different postures (standard computer monitor, tablet on a desk, tablet in the lap, semi-reclined with tablet in the lap). Reading the tablet in a semi-reclined trunk posture with the tablet in one's lap increased ($p < 0.001$) neck flexion angle (71.6%ROM) relative to reading from the standard computer monitor (6.39%ROM). Head flexion in the semi-reclined posture (19.7%ROM) and muscle activity (8.88% MVC) were similar to when reading from a standard computer monitor. Despite potentially reducing the gravitational moment produced by the head, the semi-reclined position could still compromise the force capabilities of the neck extensor musculature and result in increased strain on the passive tissues of the spine. Future work should assess how the semi-reclined position influences cervical intervertebral angles and passive tissue properties of the cervical spine. Overall, more research needs to be conducted on thoracic spine kinematics while reading a tablet computer.

1. Introduction

83% of Americans between the ages of 15 and 34 years old used a handheld computer in 2013 (smartphone, tablet, e-reader, etc.) and 64% of American households were reported to own at least one such device (US Census Bureau, 2013). Tablet sales increased 68% in 2013 (Gartner, 2014) and mobile data consumption surpassed computer data consumption in 2014 (Lella and Lipsam, 2014). Research on the biomechanical effects of this usage, and the potential musculoskeletal disorders that could occur as a result, has been unable to keep up. Many studies have examined the relationship between desktop monitor positioning and neck posture (Straker et al., 2008a; Villanueva et al., 1997) and this has resulted in ergonomic standards for computer work stations (HFES, 2007). However, the high portability and integrated touchscreen user interface of handheld computers allows for users to adapt postures which differ from typical desktop computers (Riddell et al., 2015; Straker et al., 2008b). Previous studies have quantified cervical spine posture and muscle activity when using tablet computers, however, typically only one seated posture is examined and the position of the trunk in this posture is not addressed. No study has assessed the influence of trunk posture and handheld computer usage on neck posture and muscle activity.

Previous studies have looked at head posture in relation to tablet usage. Young et al. (2012) found that tablet users exhibit greater head and neck flexion angles than previously reported with standard desktop computers. This forward head posture can increase cervical extensor strain, leading to fatigue of the extensor muscles and possibly the development of neck pain over long term use (Straker et al., 2009). This is supported by findings that tablet usage in positions requiring greater than neutral head flexion resulted in an increase in the gravitational moment produced by the weight of the head (Vasavada et al., 2015; Straker et al., 2009).

In a recent study of high school students (Shan et al., 2013), the second most common posture when using tablet usage was "semi-reclined" (preceded by "sitting" as the most common). Sitting with the hips in front of the shoulders or in a chair that leans back would posteriorly rotate the trunk into a semi-reclined posture. This could result in increased neck flexion without a corresponding increase in head flexion. The moment produced by the head would then be lessened but the neck extensor muscles would be further stretched, increasing their sarcomere length while decreasing moment arm

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length, which could lead to a decrease in moment producing capability (Vasavada et al., 1998).

The primary purpose of this study was to assess the influence of different tablet computer reading postures on neck angle, head angle, and muscle activity. In this study, participants read a standardized one-minute script on a tablet or computer monitor in four different postures. Neck angle, head angle, and muscle activity were compared between the four different reading postures. Our hypothesis was that reading with the tablet in the lap would exhibit the greatest neck flexion angles and muscle activity.

2. Materials and methods

2.1. Participant data

Nineteen participants ten male, nine female; height 157–186 cm (173.7 ± 9.04 cm), weight 48–104 kg (68.67 ± 13.2 kg) aged 18–34 (20.05 ± 1.68) years were recruited to participate in this study. The inclusion criteria for participation in this study were individuals with no previous neck injuries, chronic headaches, or allergy to rubbing alcohol. The University of Arkansas Institutional Review Board approved all methods and participants provided written informed consent.

2.2. Instrumentation

Bipolar, disposable surface Silver-Chloride electrodes were applied 2 cm bilaterally from the spinous process of the fourth cervical vertebrae (Sommerich et al., 2000). A disposable razor was used to shave the area and rubbing alcohol was used to clean the area prior to electrode application. The electrodes were then connected to a Noraxon TELEmyo DTS wireless EMG system (Noraxon U.S.A. Inc., Scottsdale, Arizona). A maximum voluntary contraction (MVC) was collected by instructing the participant to bend their head forward slightly and then extend their head against an experimenter's hands. EMG data was sampled at 1500 Hz and synced with the motion capture system.

A passive motion capture system (Qualysis AB, Göteborg, Sweden) was used to measure head and torso position. Reflective markers were placed on the following landmarks: right and left acromion process, the top of the sternum, bilateral external auditory meatus, and bilateral outer canthi (Fig. 1). Motion data was collected at a frequency of 50 Hz. To normalize head and neck posture, trials were performed with participants looking straight ahead with a neutral head posture, and then with maximum flexion, with the straight ahead trial being zero percent range of motion and the maximum flexion being 100 percent.

2.3. Reading configurations

Participants read a standardized script for 1-min in four different postures (Fig. 1, Table 1). EMG and motion capture were tracked continuously for each trial. The postures were presented to each participant in a random order.

2.4. Data analysis

Data from motion capture and electromyography sensors were continuously collected to quantify trunk/head/neck position and muscle activity, respectively. Kinematic data was processed using Visual 3D (C-Motion Inc., Maryland). The marker trajectories were low pass filtered at 6 Hz using a 2nd order dual pass Butterworth filter. Three dimension coordinate systems were created for the trunk and head using marker trajectories:

- For the head, proximal and distal endpoints were determined by finding the mid-point between the bilateral external auditory meatus (proximal) and outer canthi (distal). This defined the axis of axial rotation. The lateral bend axis was determined by finding a line perpendicular to the plane created by the four landmarks. Finally, finding the line perpendicular to both of these axes created the flexion-extension axis.
- For the trunk segment, the longitudinal axis was defined as the midpoint between the two acromion processes, and the iliac crest, which were created by digitizing these landmarks with respect to the three markers on the trunk. The remaining axes were defined in the same way as for the head segment.

Neck the neck angle was defined as the angle of the head with respect to the trunk segment about the sagittal axis. Three-dimensional neck angles were determined using a flexion-extension/lateral bend/axial rotation sequence of the head segment with respect to the trunk segment. Neck flexion angle was expressed as a percentage of neck flexion range of motion, with zero representing the upright neck posture and 100% representing the maximum neck flexion angle.

EMG data was processed using custom written code in MATLAB (Mathworks Inc., Natick, Massachusetts). For each trial, the mean of the signal was extracted. A notch filter was used to remove 60 Hz electrical contamination (Mello et al., 2007). A 30 Hz high pass 2nd order Butterworth filter was used to remove ECG contamination (Drake and Callaghan, 2006). The signals were then full wave rectified and linear enveloped at 2.5 Hz using a 2nd order Butterworth filter (Brereton and McGill, 1998). The reading trials were then normalized as a percentage of the MVC for each muscle. The processed EMG signals were downsampled to 50 Hz to align with the kinematic data.

2.5. Statistical analysis

All outcome measures were analyzed using JMP Pro (v12.1, SAS Institute Inc., Cary, NC) using a one-way repeated measures ANOVA with a within factor of reading posture (Semi-reclined/Monitor/TabletTable/TabletLap). Only the right cervical erector spinae muscles were analyzed. To analyze any significant main effects, a Tukey's HSD test was run. The exception to this was that four matched pairs t-tests (one per seated position) were run on the EMG variables to determine if there was a significant difference between the left and right EMG signals. Significance was set at $p < 0.05$ for all tests.

3. Results

3.1. Electromyography

There were no significant differences between the left and right cervical EMG (Semi-reclined $p = .5758$; Monitor $p = 0.9810$; TabLap $p = 0.8616$; TabTable $p = 0.9422$). For simplification purposes, only the results from the right cervical EMG will be presented.

There was a main effect of reading posture on mean cervical EMG ($F_{3,72} = 5.32$, $p < 0.005$). The mean cervical EMG during the semi-reclined ($p = 0.0043$, 8.88%MVC±4.99% MVC) and monitor ($p = 0.0242$, 10.03%MVC ±0.05%MVC) reading postures was significantly different from when reading the tablet on one's lap (15.93%MVC ±07.66%MVC) but not from when reading the tablet on the table (13.78%MVC ±6.79%MVC). Reading the tablet on the table versus the lap showed no significant differences in mean cervical EMG (Fig. 2).