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A radiographic investigation of cervical spine kinematics when reading a tablet in a reclined trunk position

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ABSTRACT

The purpose of this study was to use radiographic measurements to compare cervical spine kinematics in various tablet computer reading postures. Radiographs were taken of twenty-two participants reading a tablet computer in five different postures. The lower cervical spine was more flexed in the semi-reclined (-8.2 ± 3.8°) and the reclined (-14.9 ± 4.0°) tablet positions compared to an upright (-4.43 ± 4.8°) tablet posture. Of the tablet reading positions, the reclined position had the lowest gravitational moment arm (5.2 ± 2.3 cm) and a skull angle closest to neutral (-9.4 ± 11.4°), while exhibiting the largest extension in the C1-C2 joint (34.4 ± 9.1°). Altering trunk position when reading a tablet could reduce the load required to support the head, but could put the head in a more forward head posture, stretch the cervical extensor muscles, and potentially result in pain.

1. Introduction

In the past five years, tablet ownership in the United States has risen from 4% to over 50% (Pew Research Center, 2015). Sixty-two percent of elementary through high school students use tablets regularly in school (Pearson, 2015). In elementary school, tablet usage has surpassed laptop usage (Pearson, 2015) and 49% of U.S workers use a tablet occupationally (Gallup, 2015). An observational study found that 68% of mobile device users report neck pain (Berolo et al., 2011), and a 5-year cohort study found a strong association between neck/upper back pain and high mobile phone use (Gustafsson et al., 2017). This may be because the screen and keys are on the same plane, and thus larger neck flexion angles are necessary to effectively interact with the device while still viewing the screen (Gustafsson et al., 2017). Shan et al., 2013 found that 44% of adolescent tablet users report neck or shoulder pain, and that number increases to 52% for users who spend more than 2 h daily with their tablets. Laboratory studies have found that handheld computer use is associated with higher neck flexion levels and muscle activity than seen with standard desktop computer monitors (Douglas and Gallagher, 2017; Straker et al., 2008; Young et al., 2012). Prolonged neck flexion is associated with increased symptom reporting, such as neck pain or fatigue (Ariëns et al., 2001), and studies show a positive correlation between a more forward head posture and neck pain (Silva et al., 2009; Lau et al., 2010). A limitation to many of these previous tablet studies is that they on only assessed an upright seated posture; however, studies have shown that people interact with their devices in a variety of seated postures (Steelcase, 2015). Given this limitation, the purpose of our study was to determine how a commonly reported sitting posture when using a tablet computer, semi-reclined sitting (Shan et al., 2013) influenced cervical spine angles.

A global posture study found that tablets have allowed users to back away from their desks and recline while using the device, something previously not accounted for in the design of workplace stations (Steelcase, 2015). The second most common position when using a tablet was seated with the hips in front of the shoulders (rotating the trunk posteriorly), in a “semi-reclined” posture. (Shan et al., 2013). Douglas and Gallagher (2017) found that reading a tablet with a semi-reclined trunk produced lower levels of muscle activity in the cervical extensor muscles. Weston et al. (2017) also found that participants who used a tablet for an hour in a reclined chair exhibited less discomfort than participants who used the tablet in a standard chair. A caveat to this is that the reclined chair also had arm rests that allowed the participants to support their arms and allowed them to position the tablet with a more neutral head position. A previous study that measured internal cervical spine angles during tablet usage (Vasavada et al., 2015) found that the gravitational demand (ratio of the gravitational moment to the muscle moment capacity) is higher when reading a tablet on a desk compared to a neutral posture. With extended tablet usage, this larger gravitational demand could lead to faster fatigue by the cervical extensor muscles (Enoka and Duchateau, 2008). It is possible that by positioning the head in a more neutral posture, which is accomplished by a reclined reading position, the risk of muscle fatigue could be minimized.

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A potential risk of the semi-reclined tablet reading position is that it has been found to exhibit greater neck flexion angles compared to reading with an upright trunk (Douglas and Gallagher, 2017). Weston et al. (2017) also found larger neck flexion with tablet usage compared to a standard computer, but did not assess neck flexion angles between different trunk angles. This neck flexion may be initiated at the lower cervical and upper thoracic spine. As a result, the cervical extensor muscles, many of which originate on the lower cervical spine (Vasavada et al., 1998), may be passively stretched, ultimately leading to pain after extended use. Further, these muscles may experience changes in their moment arms, potentially diminishing their ability to counteract the moment produced by the head (Vasavada et al., 1998). Despite an increase in neck flexion, head posture in the semi-reclined position was shown to be similar to that when using a monitor (Douglas and Gallagher, 2017), which means that the upper cervical spine may remain extended while the lower cervical spine demonstrates a more flexed posture. This could change the muscles required to keep the head in an upright position. Douglas and Gallagher (2017) also found that neck extensor muscle activity was lower in a reclined position than in an upright tablet reading position. Decreased muscle activity could be due to a decrease in the moment arm of the head in this position, or a greater load being placed on deeper muscles and passive structures of the cervical spine.

The purpose of this study was to use radiographic measurements to determine how the cervical spine was influenced when reading a tablet in the lap during a reclined seated position. A radiographic study was used to provide a more detailed analysis of the cervical spine kinematics compared to what can be obtained using external motion capture techniques and builds on previous work (Douglas and Gallagher, 2017) that assessed semi-reclined sitting with motion capture. We hypothesized that:

(1) Participants viewing a tablet with trunk rotation would exhibit greater flexion in the lower cervical spine when compared to a neutral trunk position
(2) Increased trunk rotation would lead to a decreased moment arm of the head, and a more neutral skull angle relative to horizontal
(3) There will be greater extension in the upper intervertebral joint angles in the reading postures with trunk rotation, to compensate for the predicted lower cervical spine lordosis.

2. Materials and methods

2.1. Approach

In this study, cervical spine radiographs were taken of each participant in five different postures, three of which were when reading a tablet from in the lap. Measurements of lower cervical lordosis, moment arm, skull angle, and intervertebral joint angles were compared between the five different postures.

2.2. Participant data

Twenty-two participants (11 male: height 181.6 ± 8.6 cm, weight 78.5 ± 12.1 kg, age 21.8 ± 1.3 years; 11 female: height 144.2 ± 6.0 cm, weight 65.4 ± 10.8 kg, age 20.7 ± 0.9 years) were recruited to participate in this study over a two-month period. The inclusion criteria were no previous neck or spine injury, no chronic headaches, no allergy to rubbing alcohol, and have not been exposed to any of the following within the past two years: lumbar spine x-ray, upper GI tract x-ray, barium enema x-ray, or any CT scans. For female participants, an additional inclusion criterion was no chance of pregnancy. The University of Arkansas Institutional Review Board and Arkansas Department of Health approved all methods and participants provided written informed consent.

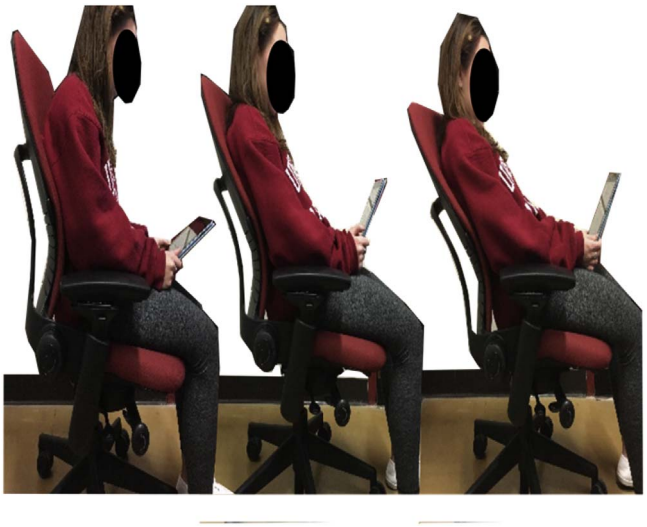

Fig. 1. Example Tablet Postures. From left to right: Upright seated, Semi-reclined, Reclined. Not pictured: Neutral, Maximum Head Flexion. The participants were not allowed to use the armrest.

2.3. Instrumentation

Disposable lead 2 mm biomarkers (Penn-Jersey X-Ray, Morrisville, PA) were placed on the spinous process of C7, suprasternal notch, right outer canthi, and right external auditory meatus. The tablet used was an iPad 2 (Apple, Cupertino, CA). A licensed radiologist technician at the Pat Walker Health Center on the University of Arkansas campus took all radiographs. Radiographs were taken at an average distance of 1.82 m away from the participant.

2.4. Postures

Cervical spine radiographs were taken from the lateral view in five distinct postures (Fig. 1). Participants were told to sit as far back in the chair as possible. They were not allowed to use the chair's armrests during any of the postures. For the tablet reading postures, the tablet was held in portrait mode.

1. Neutral head position – the participant seated with arms in lap looking straight forward
2. Maximum neck flexion - the participant seated with their head bent forward as far as they can
3. Upright seated - Reading a tablet seated posture
4. Semi-reclined - Reading a tablet when seated in a semi-reclined position, with the seat back reclined 15° to the vertical
5. Reclined - Reading a tablet when seated in a reclined position, the seat back reclined 30° to the vertical.

Images were first taken in the neutral and full flexion postures, followed by the tablet postures in a randomized order. Participants were given a 30-s rest between postures. Participants were instructed to sit in the chair and lean back as far as the chair-back allowed, and were instructed to hold the tablet while keeping their hands on their lap. To minimize deviations in hip angle, participants were instructed to sit as far back into the chair as possible. They were not instructed as to what angle to adjust the tablet to allow for a more naturalistic observation. The participant was then instructed to stare at a piece of tape centered on the tablet, while the technician took the radiograph.

2.5. Data analysis

All measurements were manually using ImageJ (version 1.51h, NIH)