Applied Ergonomics 62 (2017) 83–93

Contents lists available at ScienceDirect

Applied Ergonomics

journal homepage: www.elsevier.com/locate/apergo

A biomechanical and physiological study of office seat and tablet device interaction

Eric Weston [a, b, *], Peter Le [a, b], William S. Marras [a, b]

[a] Spine Research Institute – Biodynamics Laboratory, The Ohio State University, Columbus, OH 43210, USA
[b] Department of Integrated Systems Engineering, The Ohio State University, Columbus, OH 43210, USA

ARTICLE INFO

Article history:
Received 23 March 2016
Received in revised form
14 February 2017
Accepted 16 February 2017

Keywords:
Sitting
Mobile device
Seating discomfort

ABSTRACT

Twenty subjects performed typing tasks on a desktop computer and touch-screen tablet in two chairs for an hour each, and the effects of chair, device, and their interactions on each dependent measure were recorded. Biomechanical measures of muscle force, spinal load, and posture were examined, while discomfort was measured via heart rate variability (HRV) and subjective reports. HRV was sensitive enough to differentiate between chair and device interactions. Biomechanically, a lack of seat back mobility forced individuals to maintain an upright seating posture with increased extensor muscle forces and increased spinal compression. Effects were exacerbated by forward flexion upon interaction with a tablet device or by slouching. Office chairs should be designed with both the human and workplace task in mind and allow for reclined postures to off-load the spine. The degree of recline should be limited, however, to prevent decreased lumbar lordosis resulting from posterior hip rotation in highly reclined postures.

1. Introduction

Working adults tend to spend anywhere between about one half to 86% of the workday seated, depending on the occupation (Jans et al., 2007; Katzmarzyk et al., 2009; Toomingas et al., 2012). Prolonged seating has also been associated with musculoskeletal disorders related to low back pain (LBP), low-level static loading of the back muscles, disc degeneration, and spine stiffness (Beach et al., 2005; Callaghan and McGill, 2001; Frymoyer et al., 1980; Hales and Bernard, 1996; Holmes et al., 2015; Marras et al., 1995; Videman and Battié, 1999; Visser and van Dieen, 2006).

Trends relating to prolonged seating can be attributed to the increasing computer and deskwork associated with most jobs. In 2009, Sweden estimated that 70–75% of the workforce uses computers at work (SWEA, 2010). With the advancement of technology, computing devices have become more mobile, thereby resulting in heavier use of touch-screen tablets and smartphones (Dillon, 2014). Tablet devices originally gained popularity for personal use, but have increased in popularity within the workplace over recent years. It was estimated several years ago, that by 2017, nearly one in five tablets purchased in the United States will be used for business purposes (Dillon, 2014). Survey data has also shown that those employees that already own tablet devices spend 2.1 h daily on their tablet for work purposes, accounting for 26% of their total computing time (CDW, LLC. 2012).

It is well documented in the literature that extensive computer work serves as a risk factor for musculoskeletal disorders (Brandt et al., 2004; Ijmker et al., 2007; Lassen et al., 2004; Marcus et al., 2002; Waersted et al., 2010; Wigaeus Tornqvist et al., 2009). However, due to the sudden popularity and adoption of tablets in the workplace, little research has been performed to evaluate the risks associated with prolonged tablet use in an office setting. Sitting is the most common posture adopted during tablet computer use (Shan et al., 2013), and tablet use in a seated posture is often accompanied by forward flexion of the trunk and lack of armrest use, thereby leaving the weight of the upper body unsupported and risking back pain (Sttawarz and Benedyk, 2013).

While studies have examined how postures assumed during tablet use affect the head, neck, and upper limb over short time frames (Sttawarz and Benedyk, 2013; Vasavada et al., 2015; Young et al., 2012, 2013), none have examined how extended tablet use affects loading on the lumbar spine. Additionally, there are no studies to date that examine biomechanical measures associated with tablet use over an extended period. Thus, it remains unclear

* Corresponding author. 1971 Neil Avenue Rm 210, Columbus, OH 43210, USA.
E-mail address: weston.101@osu.edu (E. Weston).

http://dx.doi.org/10.1016/j.apergo.2017.02.013

how the combined risks of prolonged seating and consistent use of both desktop computers and portable electronic devices such as touch-screen tablets might present over time.

Discomfort is also a common issue during long periods of sedentary work (Michel and Helander, 1994; Zhang et al., 1996) and is typically measured as a subjective factor in the ergonomics literature. However, subjective discomfort ratings have been shown to be subject to factors such as aesthetic bias (Helander, 2010). Moreover, a study in automotive seating by Le et al. (2014) showed high between and within subject variability in subjective ratings of discomfort, highlighting the need for more objective discomfort measures. The use of heart rate variability (HRV) as an objective measure of discomfort is new to the ergonomics literature and deserves further exploration. Under asymptomatic conditions, the heart is not a metronome; beat to beat variation in the signal exists during tonic flux between sympathetic and parasympathetic responses in the autonomic system. Under high stress conditions or pain, sympathetic responses may increase as parasympathetic responses decrease, thereby reducing the amount of variability between beats (Appelhans and Luecken, 2008; Cohen et al., 2000; Thayer and Brosschot, 2005; Thayer and Lane, 2000, 2009). Since pain and discomfort are believed to be interrelated, it is believed that interactions between discomfort and variability in heart rate will behave similarly.

It has been noted that individuals that are asymptomatic for LBP do not perceive disc pressure or proprioceptive information about body posture well enough to discriminate between chair design features (deLooze et al., 2003). Objective discomfort derived from HRV could capture information about physiological discomfort due to tissue loading that might not otherwise be perceived by the body. Additionally, HRV can be measured continuously as opposed to the need to rely on subjective reports from subjects at the end of the experimental condition. A recent study by Le and Marras (2016) explored heart rate variability (HRV) as an objective measure associated with discomfort in order to assess differences in discomfort as subjects interacted with different workstations (standing, perching, and seating) (Le and Marras, 2016). As findings showed that HRV could differentiate between standing (high discomfort) and seating (low discomfort) over time, it is postulated that the measure may also be sensitive enough to differentiate different seated/task conditions.

The overall aim of this study was to examine how physiological and biomechanical measures are influenced by different chair and device (desktop computer and touch-screen tablet) interactions. Our hypotheses for this study were two-fold. First, given that tablet use is likely accompanied by increased torso flexion angles that could increase moment exposure to the spine, we hypothesized that the use of a touch-screen tablet over the extended period of 1 h would be associated with higher spinal loads relative to traditional desktop computer use. Second, we hypothesized that the HRV measure would be sensitive enough to differentiate between chair and device interactions.

2. Methods

2.1. Approach

A laboratory study was conducted to evaluate biomechanical and discomfort measures in relation to varied chair and device interactions. Biomechanical measures were derived from motion capture and electromyography (EMG) data collected and processed together and used in a biologically-driven, EMG-assisted spine model; this model has been validated by over thirty years of peer-reviewed research and has been described extensively in the literature (Marras and Sommerich, 1991a, 1991b; Granata and Marras, 1993; Granata and Marras, 1995; Marras and Granata, 1997; Dufour et al., 2013). Discomfort was quantified both subjectively through survey and objectively as a function of physiological heart rate variability (HRV).

2.2. Study design

A 2 × 2 repeated measures design (Fig. 1) was implemented using two different chairs (a nearly right-angled wooden chair expected to be uncomfortable and denoted as the Control Chair and the Gesture chair; Steelcase, Grand Rapids, MI, USA) and two different devices (a desktop computer running a 64-bit Windows 7 Enterprise; Microsoft Corporation, Redmond, WA, USA and an iPad2; Apple, Cupertino, CA, USA). Subjects were assigned to complete typing tasks during each of the four conditions encountered. Each condition was tested for 1 h with a 20-min recovery period in between each level, consistent with the methodology presented by Le and Marras (2016). The order in which the conditions were encountered were randomized within a predetermined counterbalanced structure to control for potential order effects.

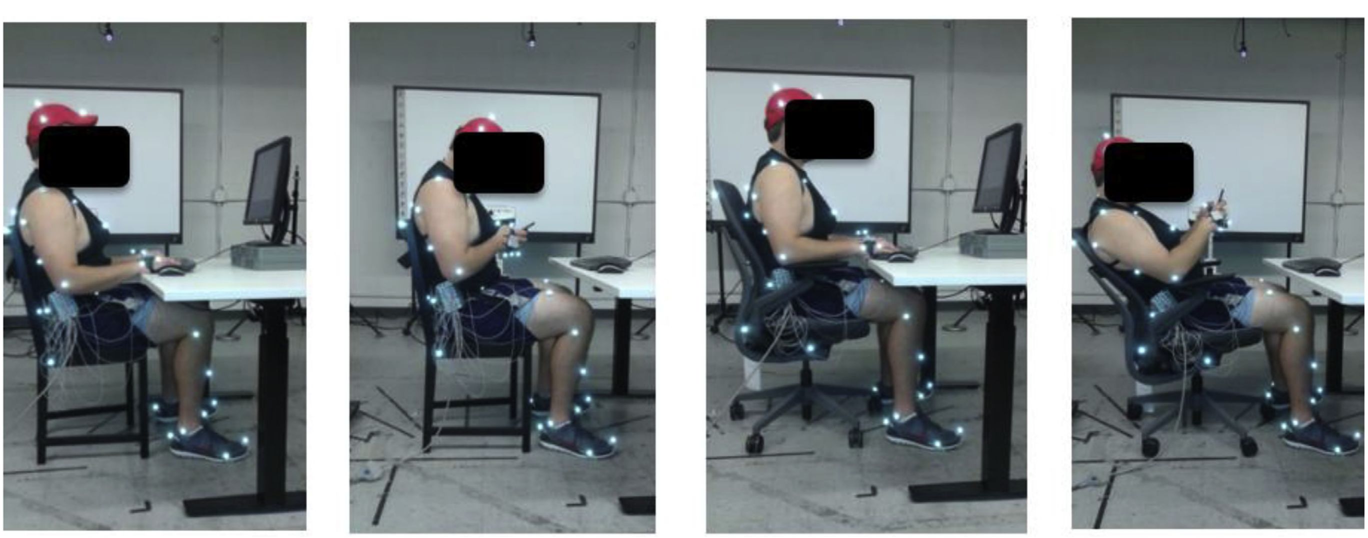

Fig. 1. Experimental setup (left to right) for the control chair/computer, control chair/tablet, Gesture chair/computer, and Gesture chair/tablet conditions.