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Evaluating the low back biomechanics of three different office workstations: Seated, standing, and perching

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ABSTRACT

The objective of this study was to evaluate how different workstations may influence physical behavior in office work through motion and how that may affect spinal loads and discomfort. Twenty subjects performed a typing task in three different workstations (seated, standing, and perching) for one hour each. Measures of postural transitions, spinal loads, discomfort, and task performance were assessed in order to understand the effects of workstation interaction over time. Results indicated that standing had the most amount of motion (6–8 shifts/min), followed by perching (3–7 shifts/min), and then seating (<1 shift/min). Standing had the highest reports of discomfort and seating the least. However, spinal loads were highest in A/P shear during standing (190N posterior shear, 407N anterior shear) compared to perching (65N posterior shear, 288N anterior shear) and seating (106N posterior shear, 287 anterior shear). These loads are below the risk threshold for shear, but may still elicit a cumulative response. Perching may induce motion through supported mobility in the perching stool, whereas standing motion may be due to postural discomfort. Office workstation designs incorporating supported movement may represent a reasonable trade-off in the costs-benefits between seating and standing.

1. Introduction

Prolonged sitting has been associated with many health concerns including increased risk of obesity, cardiovascular, metabolic disorders, and low back pain (LBP) (Brown et al., 2003; Callaghan and McGill, 2001; Frymoyer et al., 1980; Hales and Bernard, 1996; Katzmarzyk et al., 2009; Marras et al., 1995; Mummery et al., 2005). Many working adults in occupations involving prolonged periods of seating tend to spend about a half to two thirds of their workday seated within an office environment (Jans et al., 2007; Toomingas et al., 2012). To mitigate the risks associated with prolonged seated work movement is encouraged (Callaghan and McGill, 2001; Holmes et al., 2015).

The lack of motion within a seated environment imposes a physical risk to the musculoskeletal system because the tissues are not being challenged (Straker and Mathiassen, 2009). In turn, tissue tolerances decrease and intermittent external loading above the tolerance that was once able to be endured become risky (Marras and Hoboken, 2008). Prolonged sitting has also been shown in induce passive loading onto the spine (Callaghan and Dunk, 2002). This poses a problem due to the constant loading of the passive tissues. Without rest, it may induce microdamage to the ligamentous tissues and increase risk for a neuromuscular disorder (Solomonow, 2006). Encouraging movement may allow for rest of muscular and passive tissue loads.

Standing desks have become popular as an approach to counteract the effects of seating and encourage movement (Miyachi et al., 2015; MacEwen et al., 2015). In theory, standing has been reported to enhance cognition due to the stimulation of the cardiovascular system (Watanabe et al., 2007), which in turn may increase awareness (Caldwell et al., 2003). However, in terms of productivity, increased motion during standing poses concerns of loss of performance due to dual-task cost (Kahneman, 1973; Pashler, 1994). As tasks increase in difficulty and require higher cognition, the costs may be even greater (Thompson and Levine, 2011). Physically, prolonged standing has been shown to induce LBP in people who did not have a history of low back injury (Gallagher et al., 2014; Marshall et al., 2011; Tissot et al., 2009) and standing has had reports of lower extremity discomfort from blood pooling and mechanical pressure (Cham and Redfern, 2001). It is

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possible that movement from prolonged standing is due to discomfort rather than movement encouraged from the workstation. To alleviate the physical discomfort from standing, adjustable desks allowing for intermittent sitting and standing were introduced (Alkhajah et al., 2012; Ebara et al., 2008; Straker et al., 2013). Davis and Kotowski (2014) found that sit-stand workstations had lower reports of back discomfort. However, it has been found that although many workers were enthusiastic at the introduction of the sit-stand, most did not adopt the intervention due to the inability to find an acceptable posture or had lack of motivation to adjust the desk (Wilks et al., 2006).

Recently, perching has been introduced as an approach in between sitting and standing. During perching, the person leans against a spring-loaded stool to distribute the load between the legs and buttocks area while allowing for the ease of transition from perch to stand. During the perch, movement is encouraged through the mobility of the seat pan and flexion/extension of the knees. Previous studies have shown that movement during office work has been recommended to reduce swelling in the lower extremities (Stranden, 2000) and increase motion in the spine (O'Sullivan et al., 2006). The shifts in posture may allow periodic resting of the musculature through load migration between the passive tissues and to mitigate fatigue (Veiersted et al., 1990). In particular, prolonged periods of standing were associated with reports of fatigue in the lower extremities (King, 2002) and back (Kim et al., 1994). As fatigue sets in, antagonistic muscular coactivation increases in order to stabilize the posture (Granata et al., 2004) resulting in higher spinal loads (Granata and Marras, 2000). Rest breaks due to postural changes would assist in reducing prolonged static loads onto the spine (Callaghan and McGill, 2001). Previous studies have suggested adopting multiple postures and postural variation to reduce spinal loads (Callaghan and McGill, 2001; Davis and Kotowski, 2014). Hence, in our study it was postulated that a posture incorporating supported movement from perching may incur less spinal loading relative to prolonged periods of standing. However, a void exists in which we do not know how much movement is too much or not enough. It has been postulated that a moderate amount of workload (movement) may be necessary to counteract the risk (Winkel and Westgaard, 1992).

Two hypotheses are presented to evaluate the biomechanical cost-benefit of each of the different workstations. First, perching would encourage a moderate amount of movement relative to sitting and standing. Second, supported movement from perching over time would be associated with lower spinal loads relative to unsupported movement (standing). The objective of this study is to explore the biomechanics of how different postures induced by different workstations may affect spinal loads and discomfort in relation to movement.

2. Methods

2.1. Approach

A laboratory study was conducted in an attempt to understand the biomechanical and physiological cost-benefit of different workstations. Three different workstations were tested using electromyography (EMG) and motion capture and processed as a part of a biologically-driven, EMG-assisted spine model to understand the physical loads. Discomfort was recorded as a subjective report and as a function of heart rate variability (HRV) over each hour of testing. The results of this study provide output measures of spinal loads, postural transitions, and relative discomfort in relation to the workstations.

2.2. Participants

Twenty subjects (10 males and 10 females) were recruited throughout the community (age 26.5 ± 8.5 years, mass 76.5 ± 11.5 kg, and height 174.9 ± 11.5 cm). All of the subjects provided informed consent and had no reports of previous or current low back pain in the past 6 months. This study was approved by the university's institutional review board.

2.3. Experimental design

The order of the workstations was counter-balanced. A repeated measures design was utilized since each level was collected at multiple time points.

2.3.1. Independent variables

Only one condition was tested with three different levels of workstations: seated, standing, and perching. Each level was tested for 1 h with a 20-min period of recovery between levels and a 10-min period to adjust the workstation. The 1-h period of testing was chosen based upon previous studies of seating discomfort showing increased motion and physiological changes after 30–45 min (Le et al., 2014). The 20-min recovery period was chosen based upon a pilot study with 4 subjects at different rest intervals (10 min, 20 min, and 30 min) for all workstation conditions. An assessment of residuals did not show any order effects with the 20-min rest interval. During each level the subjects completed a typing task (Typing Queen Software).

2.3.2. Dependent variables

Biomechanical measures of multi-level spinal loads (compression, anterior/posterior shear, and lateral shear), postural transitions, localized subjective discomfort, physiological discomfort, and task performance were assessed.

The rationale behind the measure of spinal loading was to understand load influences between workstations as they may contribute to a cumulative response over time. Postural transitions were collected in order to evaluation possible associations between movement, spinal loading, and discomfort. Physiological discomfort (HRV) assessed to objectively quantify discomfort over time since subjective measures are highly variable in their reports (Le et al., 2014). Studies from Thayer and colleagues (Thayer and Brosschot, 2005; Thayer and Lane, 2000, 2009) as well as Appelhans and colleagues (Appelhans and Luecken, 2008), and Cohen and colleagues (Cohen et al., 2000) have discussed an interaction between pain and variability in heart rate. The heart beat is regulated by the parasympathetic branch of the autonomic nervous system. Under homeostatic (normal) conditions, both the parasympathetic and sympathetic nervous systems are in a tonic flux, thereby contributing to higher variability in the heart rate. However, during painful or stressful events the parasympathetic tone is reduced as sympathetic tone increases. As one system overrides the other, the tonic fluctuation ceases and variability decreases, which may be indicative of the brain-heart interaction response to pain. Since pain and discomfort are related, we believed that discomfort may be objectively assessed via HRV. Lastly, results from a typing task was assessed in order to evaluate the influence of working posture on task performance.

2.4. Apparatus

Three workstations were tested: seated (Aeron Chair, Herman Miller, Inc. Zeeland, MI, USA), standing, and perching (Locus Sphere, Focal Upright, North Kingstown, RI, USA). An adjustable desk was used for both seating and standing conditions (TiMOTION