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Evaluating biomechanics of user-selected sitting and standing computer workstation

Michael Y. Lin [a], Ana Barbir [b], Jack T. Dennerlein [a, b, *]

[a] Department of Environmental Health, Harvard T.H. Chan School of Public Health, 677 Huntington Avenue, Boston, MA 02115, USA
[b] Department of Physical Therapy Movement and Rehabilitation Sciences, Bouvé College of Health Sciences, Northeastern University, 360 Huntington Avenue, Boston, MA 02115, USA

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A B S T R A C T

A standing computer workstation has now become a popular modern work place intervention to reduce sedentary behavior at work. However, user's interaction related to a standing computer workstation and its differences with a sitting workstation need to be understood to assist in developing recommendations for use and set up. The study compared the differences in upper extremity posture and muscle activity between user-selected sitting and standing workstation setups. Twenty participants (10 females, 10 males) volunteered for the study. 3-D posture, surface electromyography, and user-reported discomfort were measured while completing simulated tasks with each participant's self-selected workstation setups. Sitting computer workstation associated with more non-neutral shoulder postures and greater shoulder muscle activity, while standing computer workstation induced greater wrist adduction angle and greater extensor carpi radialis muscle activity. Sitting computer workstation also associated with greater shoulder abduction postural variation (90th–10th percentile) while standing computer workstation associated with greater variation for should rotation and wrist extension. Users reported similar overall discomfort levels within the first 10 min of work but had more than twice as much discomfort while standing than sitting after 45 min; with most discomfort reported in the low back for standing and shoulder for sitting. These different measures provide understanding in users' different interactions with sitting and standing and by alternating between the two configurations in short bouts may be a way of changing the loading pattern on the upper extremity.

1. Introduction

In the field of applied ergonomics, the setup of the seated computer workstation is a major target in the prevention and mitigation of computer work related musculoskeletal disorders. This approach is based on the idea that specific placement and arrangement of a computer workstation affect upper extremity biomechanics (Burgess-Limerick, 1999; Dennerlein and Johnson, 2006a,b; Jensen, 1998).

In the modern workplace, highly adjustable sit-stand workstations have become very popular with some evidence suggesting that they reduce musculoskeletal discomfort and improve worker wellbeing (Wilks et al., 2006). The review by Karakolis and Callaghan 2014 concluded that use of sit-stand workstations is associated with reduced discomfort. For example, Pronk et al. have shown that standing workstations reduce the discomfort of upper extremity (Pronk et al., 2011). Robertson also demonstrated that those who take advantage of the standing option in a sit-to-stand workstation had less discomfort, improved their performance, and varied their posture more (Robertson et al., 2013), which can be protective of discomfort (Davis et al., 2009; Srinivasan and Mathiassen, 2012). Comparing to sitting, a standing workstation removes the task chair and requires users to find alternative ways of arm and body support (Marshall et al., 2011; Nelson-Wong and Callaghan, 2010). Thus, a standing workstation may afford users to change their postures and muscle activities more frequently while seeking support, compared to a sitting workstation. In addition, changing using a sit-stand workstation can change postures of the lumbar spine during sitting (Karakolis et al., 2016). However, how standing computer workstations impact user's upper extremity posture and muscle activity differently from sitting

* Corresponding author. Northeastern University, 360 Huntington Avenue 301 Robinson Hall, Boston, MA 02115, USA.
E-mail address: j.dennerlein@northeastern.edu (J.T. Dennerlein).

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workstations remains unclear.

These highly adjustable workstations provide a number of possible workstation set up configurations for both sitting and standing that in turn affect the biomechanics of the users. Previous work done by Asundi has demonstrated that when given adjustable workstations, users often select set ups that are not within the recommended guidelines (Asundi et al., 2011). Asundi also went on to show that the postures while using these non-conforming workstation setups were well within the guidelines.

Lin et al., 2016 demonstrated that many users chose workstation sets ups for a sit-to-stand work station that do not completely conform to recommended guidelines for seated work and often for standing work (Lin et al., 2016), work surface heights were lower than guidelines for standing work (Sanders and McCormick, 1993). Lin et al., 2016 did not report the effects of the wide variability of workstation set up selected by the users on the postures and muscle activity.

Therefore, the primary objective of this study is to evaluate the magnitude and variations of postures, muscle activity and discomfort for both sitting and standing workstations based on users' preferred workstation set up. As part of a psychophysical workstation protocol, where users self-selected their desk height, keyboard, mouse, and monitor positions (Lin et al., 2016), users' upper extremity posture and muscle activity were measured while they were sitting and standing. Due to the change in workstation setup in standing, it is hypothesized that more neutral postures, lower muscle activity, and lower perceived discomfort will associate with a standing computer workstation compared to a sitting computer workstation. It is also hypothesized that this reduction in support during standing will be associated with greater joint movement and more dynamic muscle activity ranges compared to the sitting workstation.

2. Methods

Twenty adult right-handed participants (10 males and 10 females) with no history of neck or upper extremity musculoskeletal injuries or pain volunteered and provided written informed consent for the repeated measure laboratory study. We restricted the recruited participants to be shorter than 185 cm and taller than 150 cm in order to be able to utilize the full range of adjustments of the workstation. Their average anthropometric measurements are provided in Table 1. All protocols and informed consent forms were approved by Northeastern University Human Subject Research Protection. The 3-h study protocol consisted of four 45-min sessions alternating between standing and sitting; the order of standing and sitting was balanced across participants. The 45-min duration was chosen so that each session would be long enough for users to potentially develop early sign of fatigue or pain, if any, under each workstation setting (Gallagher et al., 2014). During each 45-min session, the participants were asked to complete a set of typical computer tasks involving both keyboard and mouse work.

The data for this study were collected as part of psychophysical protocol where participants self-selected their workstation with the instruction to adjust the workstation to a point where they find the workstation to be comfortable over four 45 min periods (Lin et al., 2016). The four periods alternated between sitting and standing at a highly adjustable workstation with the first period assignment to sitting or standing was randomized and counterbalanced across participants. The final workstation set ups selected by the users through this psychophysical protocol are provided in Table 2.

All participants' activities and interactions with the workstation were recorded real time continuously using 3-D motion analysis and surface electromyography. The 10th percentile, median and 90th percentile values of user's posture and muscle effort data were calculated for each of the four 45 min periods (Dennerlein and Johnson, 2006a,b; Jonsson, 1988). In addition, after each period, participants provided feedback on their discomfort level using a standardized survey questionnaire.

Table 1
Anthropometric measures of means (standard deviations) across all participants.

	Males (N = 10)	Females (N = 10)	All
Age (yrs)	29 (5)	26(5)	27.4 (5)
Height (cm)	179 (6)	164 (5)	171 (9)
Weight (kg)	81 (18)	61 (11)	71 (18)
Hand Length (cm)	19 (0.9)	18 (0.6)	18 (1.1)
Hand breadth (cm)	9.6 (0.6)	8.3 (0.4)	9 (1)
Shoulder width (cm)	44 (3)	40 (2)	42 (3)
Forearm length (cm)	46 (2)	41 (2)	44 (3)
Chair height (cm)	49 (2)	47 (1)	48 (2)

2.1. Workstation conditions and experiment protocol and tasks

Each participant completed a series of standardized computer tasks four times, during each of the four 45 min bouts alternating between sitting and standing for each bout. All participants used the same sit-stand workstation consisted of a height-adjustable desk (Airtouch®, Steelcase), a wireless mouse (M325®, Logitech), a wireless keyboard (Slim Bluetooth keyboard, Hewlett-Packard), and a 19-inch LCD monitor (DELL) supported with an easy-to-adjust mechanical arm (LX Desk Mount LCD Arm, Ergotron). For all workstation conditions, a chair without arm rest (Ergonomic Task Chair, casted by Superior Furniture, TX) was provided to the participant with the chair height adjusted by the experimenter such that the participant's feet remained on the floor and the thighs were parallel with the floor throughout the experiment.

Each 45 min bout was parsed into four 11.25-min segments. At the end of each segment, the experimenter interrupted the user and reset the workstation to one of several extreme positions. An example of such extreme positions would be placing all of user's mouse, keyboard, and monitor at the very back of the desk. The extreme positions were selected at random to avoid biasing users i one direction per the psychophysical protocol adapted from Snook and Ciriello (1991). The participant had to readjust the height of the desk, the position of the keyboard and mouse, and the three-dimensional position and angle of the monitor to her/his

Table 2
Final device locations relative to user's reference body landmark locations for self-selected computer workstations: across participant marginal means and standard errors.

(Distance in cm)	Workstation*	
	Sit	Stand
MOUSE X (In front of)		
Reference Sternum	54 (1)	54 (1)
MOUSE Y (Right of)		
Reference Sternum	31 (1)	33 (1)
Keyboard X (In front)		
Reference Sternum	56 (1)	57 (1)
Keyboard Y (Right of)		
Reference Sternum	3 (1)	5 (1)
Desk Height (above)		
Reference Elbow	3 (1)	−5 (1)
Monitor Height (above)		
Reference Eye Level	−9 (3)	−13 (3)
Monitor Angle (°)	8 (1)	18 (1)

*Note: Distance from front center front edge to back edge is 120 mm, to ‘g’ and ‘h’ key is 65 mm. Dimension of the keyboard is 285 × 120 mm.

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