Active Workstations and Their Effect on Performance and Workload

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Abstract

Over the past 30 years, work has become more sedentary due to increased computer desk work and added automation, which has led to the development of major health consequences like obesity and diabetes. One promising intervention for decreasing sedentariness is the incorporation of active workstations that promote movement; however the implications of these systems have not been explored thoroughly. The present study looked at the impact of active workstations (sit/stand and treadmill desks) on performance measures, workload, and discomfort during standard office work-type tasks. Thirty-one subjects were tested under three conditions–sitting, standing, walking–in a within subjects design. Each subject performed a series of mousing, typing, and cognitive tasks during each condition and provided subjective ratings of workload and discomfort. Walking produced significant performance decrements on mousing and typing tasks compared to either sitting or standing, but equivalent performance was observed during cognitive tasks. Overall workload was significantly higher during the walking condition versus sitting and standing, with workload increasing over time during the walking condition. Discomfort was rated significantly higher during standing and walking conditions compared to sitting, with the highest rating occurring in the legs. These results help in understanding the effects of these workstations on users and can lead to the development of implementation recommendations in terms of tasks and duration-of-use for the promotion of health and the prevention of performance decrement and body discomfort.

Introduction

Over the last few decades the United States has seen a gradual shift from manual labor to sedentary work, with more than 56% of employed people using a computer at work (U.S. Census Bureau, 2003). This in turn has contributed to an increase in workplace sedentary behavior, specifically time spent sitting, with estimates as high as six hours per day (Brown et al., 2003) and 82% of normal work hours (Parry & Straker, 2013). Due to the link between sedentary behavior and increased rates of all-cause mortality (Biswas et al., 2015), there has been a renewed emphasis on health interventions at work, specifically active workstations. Active workstations are desks that give users the flexibility to sit, stand, or use equipment (such as a treadmill or pedals) that allows for light physical activity. Previous studies have concluded that replacing sitting with either standing or walking can significantly increase energy expenditure (Levine & Miller, 2007; Straker et al., 2009). In a 1-year prospective trial on sedentary office worker utilization of treadmill desks, daily physical activity of subjects increased by 25%, and sedentary time decreased by an average of 40 minutes per day, compared to baseline (Koepp et al., 2102). They concluded that access to a treadmill desk not only provided health benefits but also showed no significant decrement in work performance.

The first study involving treadmill desks, conducted by Edelson and Danoffz in 1989, examined typing performance, subjective stress levels, musculoskeletal complaints, and arousal while having subjects perform tasks in both sitting and walking conditions. While finding no performance decrement, Edelson and Danoff found a decrease in subjective discomfort levels in the buttocks and lower back, decreased stress, and an increase in arousal levels. However, recent research has shown a 6-14% decrease in typing speed while walking on a treadmill (John, et al., 2009; Funk et al., 2009; Straker et al., 2010; Funk et al., 2012). Straker, Levine and Campbell (2009) investigated the differences between sitting, standing, walking, and cycling on typing and mouse performance. While this study found no difference in typing performance between sitting and standing conditions, both cycling and walking conditions showed a small decrease in actual and perceived typing speed. Fine motor control tasks, such as those requiring the use of a mouse, were found to suffer a greater performance decrement than typing. There is also evidence that walking speed is a factor; Funk et al. (2012) found that walking speeds of 1.3 and 3.2 km per hour showed a significant performance decrement in typing speed, while a walking speed of 2.25 km per hour showed no significant difference compared to sitting. This seems to indicate a possible "zone" for walking speed that avoids hampering typing performance while still providing health benefits to users.

Cognitive functioning is an important aspect in computer use with tasks involving attention, memory, visual search, speech quality, and reading comprehension. These tasks have not been as well researched as typing and mouse usage, but serve an important function in general computer-based work. The few studies to date have shown only minor performance decrements, as measured by reading comprehension and GRE math tasks, during walking conditions. Meanwhile selective attention, memory, and speech quality tasks showed slightly improved performance during light physical activity (John et al., 2009, Cox et al., 2011, Ohlinger et al., 2011). These studies focused on walking as compared to sitting with little regard to standing–which is still an important aspect of these systems. Therefore, this area of research requires more in-depth focus of relevant work-tasks (across the sitting, standing, and walking conditions) to increase our understanding of how these systems could be implemented.

Operator workload is a key component in human factors research and is considered multidimensional (Moray, 1979), in that it takes into account both physical and mental demands (Reid & Nygren, 1988). It is used to understand how tasks or procedures affect the operator's resources in order to help guide designers and engineers in system design. If a task produces a high workload for the operator their performance may decrease due to behavioral changes (such as increased effort and frustration), leading to decreased satisfaction (Kokini et al., 2011). This is something that should be avoided when designing a system, and knowing how active workstations affect an operator's physical and mental resources is critical to understanding how procedures and tasks should be organized and executed.

High levels of workload, both physical and mental, may also lead to musculoskeletal discomfort, which has been an area of concern with extended repetitive computer use (including typing). Traditional investigations of this discomfort have focused only on the upper extremities (e.g. a recent study by Onyebeke et al. (2014) showed that forearm support can significantly lower the subjective ratings of discomfort during mousing). However, with active workstations, full body discomfort becomes important and few studies have considered these ratings. Straker et al. (2010) attempted to assess full body discomfort by having participants indicate the location and severity of discomfort after walking. One limitation of this study was they did not have specific areas of the body they focused on regarding discomfort and was only given post-hoc. In order to understand how active workstations affect operators' physical workload, pre- and post-task assessments are needed.

This study aimed to identify the effects of active workstation use on task performance, workload, and physical discomfort. The hypotheses for this study were that 1) the treadmill workstation use would negatively impact performance, workload, and discomfort and that 2) cognitive task performance would not degrade when either standing or walking.

Methods

Subjects

Participants were students (16 males and 15 females) recruited from the University at Buffalo with an average age of 23.19 (SD 3.06). This sample population was selected for the purpose of testing near-future worker populations and to get a sense of baseline measures that would be useful for future studies. All participants were pre-screened for previous musculoskeletal injuries prior to the study and exclusion criteria included pregnancy and any prior history of a physical disorder affecting the arms, shoulders, legs, or lower back. All participants completed the Physical Activity Readiness Questionnaire (PAR-Q) to ensure suitability to perform physical activity (Thomas et al., 1992).

Procedures

Participants completed one experimental session that lasted approximately three hours. A within-subjects experimental design was used, with all participants completing the trials using each of the three workstation configurations (i.e. sitting, standing, and walking). At the start of the session, participants completed demographic and physical activity questionnaires and were instrumented with the heart rate monitor chest strap. Prior to beginning the experiment, the participants filled out a modified CR-10 Borg Scale (Borg, 1982) to determine their baseline discomfort over the previous seven days with respect to four areas of the body: neck, shoulders and upper back (SUB), lower back (LB), and legs. Resting heart rate was then recorded (based on the minimum heart rate measured during a two minute sample while the participant rested quietly in a supine position).

The experiment consisted of 3 trials (seated, standing, and walking) where the first trial was always the seated condition and was used for baseline testing. The order of the last two conditions (standing and walking) was counterbalanced. Between conditions, participants were given sufficient rest of at least five minutes. Each condition lasted approximately 45 minutes.

Before each trial the workstation was adjusted properly for each participant based on ergonomic recommendations. For baseline testing in the sitting position, the treadmill was removed and the participants sat on an office stool which was adjusted appropriately so the height of the desk was just below their elbows. For the standing and walking conditions the participants' elbow height, measured from the ground to the elbow (when at a 90 degree angle), was used to adjust the height of the desk so that it was the same across all of the testing conditions. The monitor was adjusted so that the participants' eyes were level with the top of the screen. This allowed for a proper 15-20° downward viewing angle and was set at a distance of 30" from the participant.

Once the workstation was fully adjusted for the participant, the testing began. Participants first reported their discomfort in the four aforementioned body areas, and then began the computer tasks. Each trial consisted of a series of computer-based tasks described below. The order of the tasks within each trial was alternated and all trials consisted of a five-minute typing task in the middle.

Workload was measured using two assessment methods, NASA Task Load Index (TLX) and Modified Cooper Harper (MCH) (Hart & Staveland, 1988; Wierwille & Casali, 1983). The MCH typically is used as a secondary assessment method to reinforce the primary workload assessment technique. It also has the ability to give practitioners a more accurate picture of workload if it is given during a task. The TLX was administered at the end of each trial and was used to assess the workload for the entire condition. The MCH was used to assess workload throughout each trial and was given periodically three times during each block. This allowed assessment of workload changes throughout the trial.

Upon completion of each trial, the participant reported their final discomfort rating. At the end of all three trials, participants completed a post-experiment survey where they indicated their preference of workstation type and were then debriefed.

Tasks

Components of office work were simulated through a series of keyboard and mousing tasks implemented using Microsoft Word and the Psychology Experiment Building Language (PEBL, http://pebl.sourceforge.net/) environment. Each task was selected to assess a characteristic of work performance that was hypothesized to be influenced by workstation configuration. Tasks were categorized into three areas: mousing, cognition, and keyboarding. Each task lasted two to five minutes to mimic the distribution and transition of tasks typically encountered during a work day and to minimize the potential for any learning or fatigue effect from extended task performance. Participants were instructed to carefully read the task directions and ask any clarification questions. Tasks order was changed between trials to minimize expectation and task sequencing was automated to minimize experimenter interference.

Mousing Tasks. Mousing tasks were used to assess fine motor control in different workstation configurations. Since mousing accounts for one to two-thirds of general computer use (Keir, 2010), the trials consisted of 50% mousing tasks. Executive function and fine motor control was assessed using the Connections task, which involves selecting icons in ascending order on the screen (Salthouse et al., 2000). A Fitts Law task was used to assess speed accuracy tradeoffs (Fitts, 1992). Cursor positioning, required for link or icon selection, was tested using the Pursuit Rotor task (Piper, 2011).

Cognition Tasks. Hand idle-time represents a significant portion of the time spent during computer work. While the hands may be mostly idle, users are often focusing on the screen performing tasks such as reading or visual search. One task (Ant) tested attention and the effect of presented distractors on reaction time and accuracy (Fan et al., 2002). A memory span task (Corsi) was used to assess short-term memory (Kessels et al., 2000). The ability to find matching pairs in an array of assorted visual cues (Switcher task) quantified visual search and “cognitive flexibility” (Ahonen et al., 2012). In addition, perception of visual cues was assessed by the participant’s ability to estimate object travel across the screen (Webb et al., 2011).

Keyboarding Tasks. The remainder of computer-use time involved keyboaring. All trials included a typing task that was placed in the middle of each session and lasted five minutes. Participants were instructed to focus on both speed and accuracy equally. Three different passages were used, each approximately 370 words in length. The order changed between subjects. The passages were taken from classic literature and were tested for similar reading levels using the Flesch-Kincaid Grade Level test.

Equipment

Participants used an adjustable workstation for all conditions of this experiment: a TR800-DT7 treadmill desk from LifeSpan (Salt Lake City, UT). Figure 1 shows the experimental set-up for the standing condition, including the workstation and computer peripherals. The work surface can be electronically adjusted to accommodate varying participant heights. The treadmill portion attached to the base of the desk and was removed for the sitting condition.

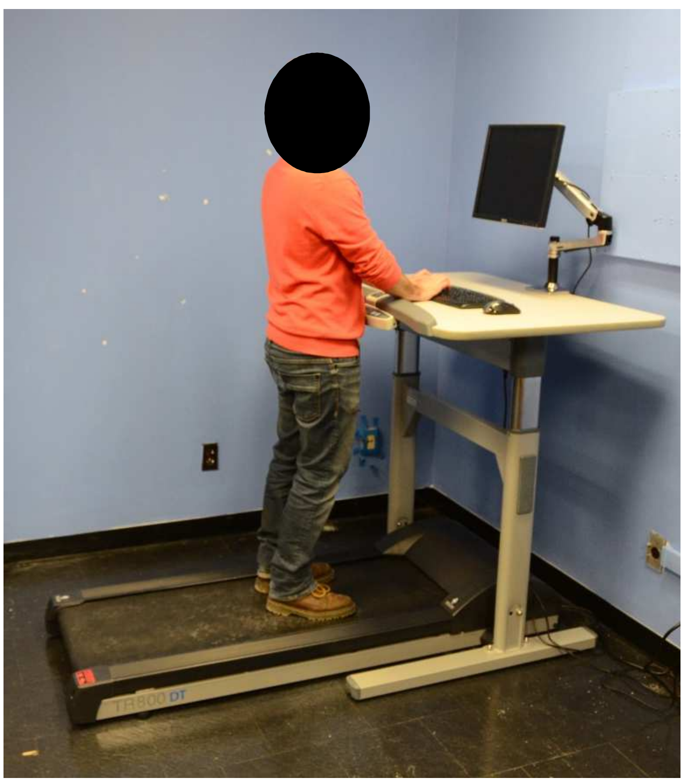

Figure 1. Workstation setup during standing trial

On the work surface, participants used a wireless keyboard and mouse while viewing a 23” monitor attached to a fully articulating swivel arm (Ergotron). Heart rate was recorded using a chest strap heart rate monitor that recorded R-R intervals (Polar RS800x from Polar USA, Lake Success, NY).

Statistical Analysis

Dependent measures collected through the PEBL software consisted of performance outcomes (reaction time, accuracy, total task time) for each of the tasks. Perceived workload was assessed using both the MCH (given three times during each trial) and TLX (given after each trial; see Figure 2). Perceived discomfort increment (focusing on neck, shoulder and upper back, lower back, and legs) was assessed using a modified Borg CR-10 scale (Nobel et al, 1983) and was calculated by taking the difference between the pre- and post-trial measurements. Heart rate was collected throughout each trial and % heart rate reserve (%HRR) was calculated by $\frac{HR\ avg. - Rest\ HR}{HR\ max - Rest\ HR}\ x\ 100$. Resting HR was assessed before experiment started and HR_{max} = 220 – age for each participant.

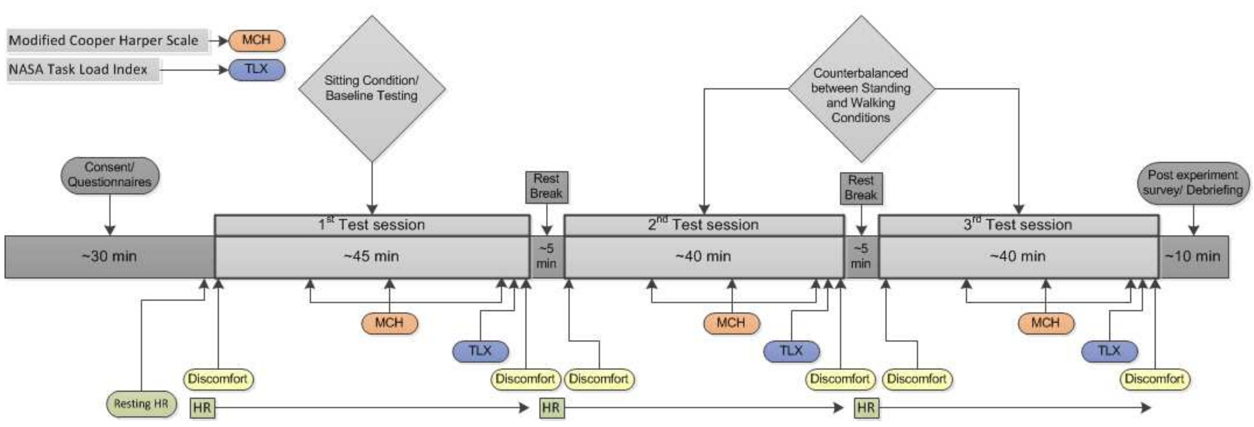

Figure 2. Timeline of Experimental session

Separate mixed-factor analyses of variance (ANOVA) were used to test the effect of workstation condition on each dependent variable. Significance was set at α = 0.05. The assumptions of the ANOVA model were tested for each variable. Post-hoc analysis was run using Tukey's HSD to test pairwise comparisons between the sitting, standing, and walking conditions. All statistical analysis was performed using Minitab version 16 (Minitab, Inc., State College, PA).

Results

Workload

NASA TLX. Overall weighted workload assessed by the TLX showed the walking condition had a significantly higher rating of workload ($p < 0.001$) than the sitting and standing conditions (see Figure 3). A main effect of task condition was observed for the physical ($p < 0.001$), temporal ($p = 0.035$), performance ($p = 0.007$), effort ($p = 0.032$), and frustration ($p = 0.002$) subscales. Mental workload was not significantly different by condition ($p = 0.25$).

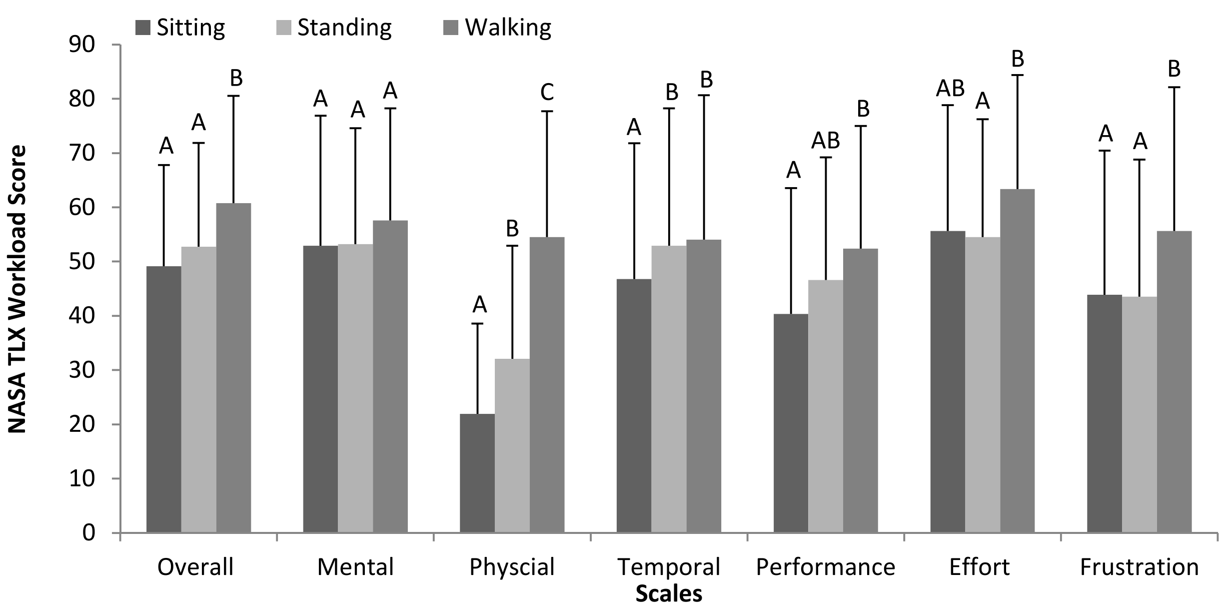

Figure 3. Average TLX overall and subscale scores. Error bars indicate the standard deviation. Letters above the bars indicate a significant pairwise comparison within the subscale found using Tukey's HSD.

The walking condition had the highest perceived workload on the effort and mental subscales. There was the greatest difference between conditions for the physical workload level, with 2.5x higher perceived physical workload for the walking condition when compared to the sitting condition and a 50% increase in physical workload between the standing and sitting conditions. Perceived frustration was ~25% higher for the walking condition than either the sitting or standing conditions. For temporal workload, walking and standing were equivalent and this was significantly higher than the sitting condition.

MCH. There were significant main effects of task condition and time on MCH workload ratings ($p < 0.001$ for each). The walking condition resulted in ~30% higher ratings than both the sitting and standing tasks, which had equivalent ratings (see Figure 4). Participants reported lower workload at Time 1 and higher levels at Times 2 and 3; however the increase between Times 2 and 3 was not significant. As the task condition by time interaction was not significant ($p = 0.72$), all conditions resulted in a similar change in perceived workload over time.

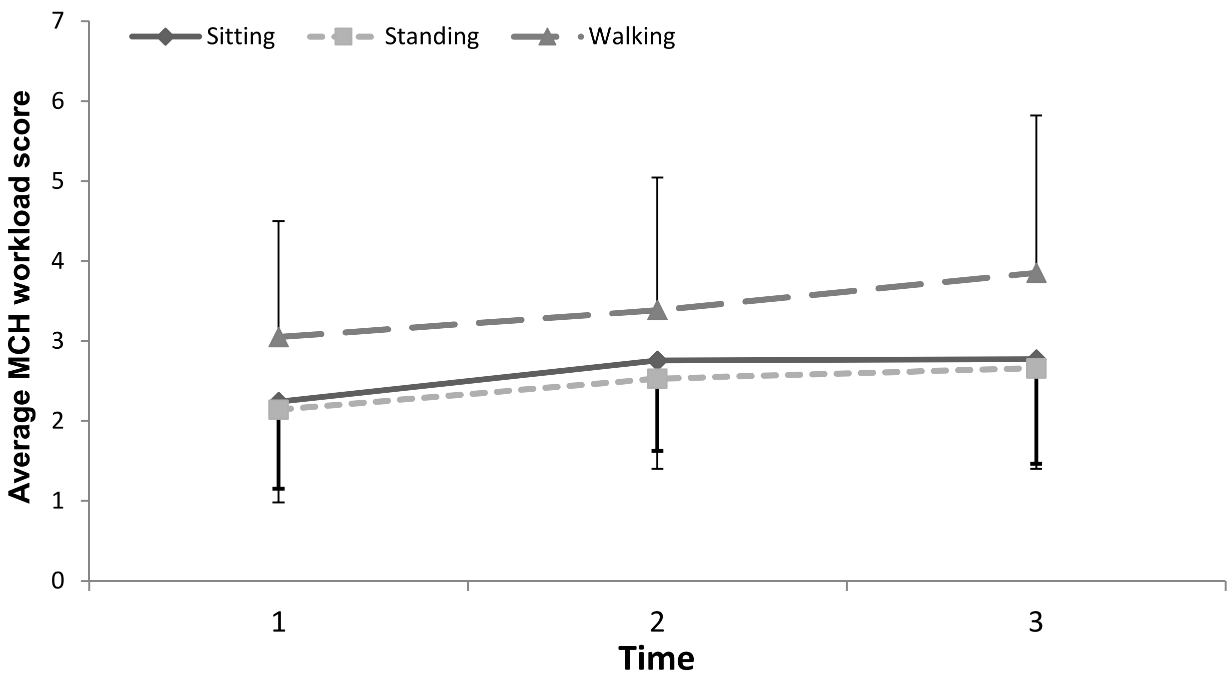

Figure 4. Average MCH scores at the three time points during the trial. Error bars indicate the standard deviation; thicker line associated with sitting condition.

Discomfort

Incremental discomfort ratings (see Figure 5) show a significant increase in the walking condition for both the legs and upper back (p = 0.001 and p = 0.026, respectively) compared to sitting. The standing condition showed a significant increase in reported leg discomfort (p < 0.001) over sitting with the increase being larger than that of walking. Discomfort in the legs had the largest increase in discomfort with a rating 4x higher in both the standing and walking conditions compared to sitting.

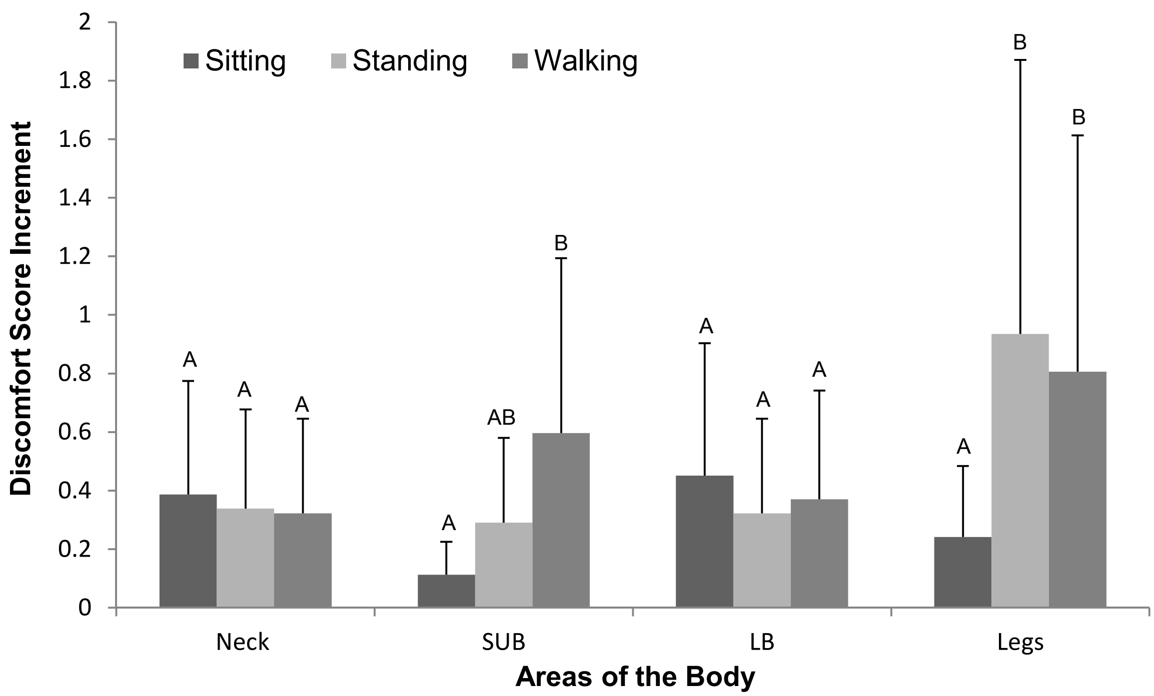

Figure 5. Discomfort between conditions. Error bars indicate the standard deviation. Letters indicate Tukey's Post hoc HSD.

Task Performance

Mousing Tasks. Fine motor control was significantly affected by the task condition (see Table 1). Participants made on average three fewer connections in the walking and sitting conditions compared to the standing condition (p < 0.001). Fitts' task movement time was approximately 100 msec. longer for walking compared to standing; however it was equivalent to sitting (main effect p < 0.001). Dexterity reaction time was longest for the sitting task (1827.8 msec.) and shortest for the standing task (1672.6 msec.). During the pursuit rotor task, participants spent significantly less time on target and had larger target deviations while walking compared to sitting and standing (p = 0.003).

Table 1. Performance measures, mean (standard deviation), between conditions and their respective p-values. * Indicates significant main effect. Superscript A, B, and C indicate significant within task pairwise comparisons using Tukey's HSD.

Task	Sitting	Standing	Walking	P-value
Mousing				
Connection Length*	25.1 (5.1)^{A}	28.8 (4.9)^{B}	25.2 (4.7)^{A}	<0.001
Dexterity (msec)*	1827.8 (332.7)^{A}	1672.6 (348.2)^{B}	1767.3 (223.95)^{AB}	0.004
Fitts (msec)*	1190.4 (147.6)^{A}	1103.3 (163.4)^{B}	1215.4 (182.6)^{A}	<0.001
Pursuit Target (msec)*	10360.7 (2107.9)^{A}	11287.1 (2001.1)^{B}	8261.5 (2048.3)^{C}	<0.001
Pursuit Deviation*	22.9 (10.4)^{A}	19.8 (6.2)^{A}	29.6 (19.5)^{B}	0.003
Cognition				
Ant Errors	2.16 (3.9)	1.48 (2.2)	1.81 (2.4)	0.32
Ant RT (msec)	591.3 (101.4)	570.1 (79.7)	567.6 (92.6)	0.065
Ant Accuracy	0.955 (0.081)	0.969 (0.046)	0.962 (0.05)	0.32
Corsi Correct	9.61 (1.94)	10.16 (1.92)	10.03 (2.47)	0.29
Corsi Memory	5.806 (0.97)	6.081 (0.96)	6.016 (1.23)	0.29
Switch Time (msec)*	2034.2 (446.3)^{A}	1908.3 (529.8)^{B}	1920.5 (447.6)^{B}	0.011
Timewall (sec)*	0.08 (0.055)^{A}	0.052 (0.022)^{B}	0.053 (0.017)^{B}	0.001
Keyboarding				
WPM*	47.3 (23.1)^{A}	46.7 (20.6)^{A}	43.6 (20.7)^{B}	<0.001
Typing Errors	5.2 (4.3)	5.5 (5.1)	5.7 (5.2)	0.77

Cognition Tasks. Tasks requiring the participants to perform cognitive tasks (see Table 1) showed that workstation type only affected time-based performance, switch time (p = 0.011) and time perception (p = 0.001). In both cases, participants performed most slowly in the sitting condition and equally for standing and walking. Specifically, switch time was approximately 100 msec longer with sitting and timewall reaction was approximately 50% longer. Error rates and accuracy were not significantly different. Memory was also found not to be affected by workstation type.

Keyboard Tasks. Typing showed a main effect for words per minute (WPM) on performance during the walking condition (see Table 1). Typing was shown to be significantly slower during the walking condition ($p < 0.001$) compared to both the sitting and standing conditions. Typing errors, however, were not found to be significant ($p < 0.05$) across all conditions.

Task Intensity

Percent heart rate reserve (%HRR), an indicator of physical task intensity, was significantly different between workstation conditions ($p < 0.001$). Task intensity for walking was twice as high as standing, and standing was almost 4x more intense than sitting (see Figure 6).

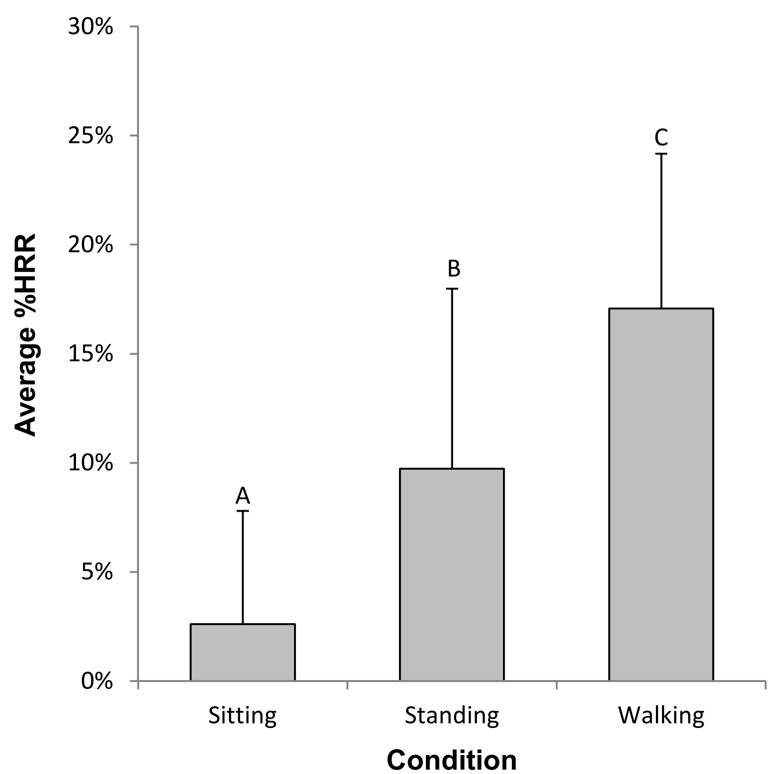

Figure 6. Average %HRR between conditions. Error bars indicate standard deviation. Letters represent significant Tukey's post-hoc comparison.

Discussion

Workload

The TLX assessment showed subjects reported significantly higher overall workload during the walking condition compared to sitting and standing. When looking at the individual subscales, Physical Demand showed the greatest difference between all three conditions with walking producing the highest score. The Effort and Frustration were similar to the Overall score, with the walking condition having a significantly higher score than both sitting and standing conditions.

This study strongly supports the hypothesis that walking produces a higher subjective workload for subjects compared to sitting and standing. It has been shown in previous research (Regnaux et al., 2006) that walking requires attentional resources, with longer reaction times (RT) for both simple and complex tasks. However, the current experiment found opposite results with attention tasks, showing lower RT's during the walking condition. The addition of light physical activity may have placed more demands on the subjects while they were being asked to complete the same tasks. This led to an increased level of frustration (which can have motivating effects by increasing overall effort; Spector, 1978), and may have led to the increased cognitive task performance. However, if effort and frustration exceed a certain threshold, this may have negative implications for work satisfaction, perceived usability, and work performance.

During the task, the MCH showed a significantly higher subjective workload rating throughout the trial during the walking condition compared to both sitting and standing. Similar to the TLX, the assessment showed a gradual increase in workload over time during walking. Both sitting and standing conditions showed a similar trajectory from the first to the second assessment; however they leveled off from the second to the third assessment. These results serve as a secondary assessment of workload and support the results from the TLX. The increase in workload during the walking condition could be an indication of increasing frustration stemming from the decreasing availability of resources over time (Yeh & Wickens, 1988) as those resources are not being replenished (Davies & Parasuraman, 1982). This decreasing availability of resources could help to explain the increase in effort and frustration that was shown in the post task TLX results.

The physical workload of subjects, as assessed by %HRR, showed significant differences among all of the conditions, with walking having the highest value. %HRR is a measure of task intensity and confirms that there was a significant increase in physical demands across all conditions. This validates the subjective measures of physical workload assessed by the TLX. These results also suggest a possible correlation between the physical demands placed on the subjects and their subjective ratings of overall workload. Lastly, standing resulted in a significant increase in %HRR compared to sitting. This indicates that one may still receive some health benefits from simply standing (as it increases your heart rate).

The Physical Demand subscale shows, a higher perceived physical workload in the standing and walking conditions. Additionally, the increase in discomfort across all conditions and across all four areas of the body suggests the potentially negative impact these workstations could have on the users' body. The legs showed the greatest increase in discomfort with a rating 4x higher in both the standing and walking conditions compared to sitting. Evidence for this hypothesis was found as walking showed an increase in discomfort. Straker et al. (2010) had similar findings with participants reporting discomfort in the legs after walking, but those assessments were only taken after the trial (thus there were no baseline measure with which to compare).

Lastly, results showed that standing caused the greatest increase in average discomfort of legs, highlighting the importance of static postures in contributing to fatigue and discomfort. These results may indicate the need for limiting the time spent standing and walking to between 30 and 45 minutes.

Task Performance

Fine motor control tasks involving the mouse showed an increase in performance across all measures, with all but one task being significant, during the standing condition compared to sitting. The walking condition showed a decrease in performance among all the tasks, with all but two being significant, compared to sitting. These results strongly support the hypothesis that the walking condition would show a decrease in task performance on mousing tasks. The results from the standing condition may be from the increased range of motion afforded while standing that could lead to an increase in fine motor control. Conversely, walking produces excess movement in the upper body, thereby degrading fine motor control.

Similar results have been found in previous research regarding performance decrement in fine motor control tasks during walking trials. John et al. (2009), while testing mouse clicking and drag-and-drop tasks, found a 6-8% decrease in performance compared to sitting. That study, however, did not have a standing condition. Straker et al. (2010) though had both sitting and standing conditions and showed a 14% decrease in mouse pointing speed and 106% increase in error rate for subjects in the walking condition. They did also see a decrease in mouse pointing speed during the standing condition compared to sitting (which differs from the results of the present study, even though a Fitts' law task was used in both cases).

The results from the typing task showed the walking condition produced an 8% decrease in WPM ($p < 0.001$) compared to sitting. Standing showed decreased performance on both measurements of typing, but was not significant. These results support the hypothesis that typing performance would be negatively impacted by walking, and do agree with recent research that shows significant decreases in typing speed with no difference in error rate while walking (John et al., 2009; Straker et al., 2010; Thompson & Levine, 2011; Funk et al., 2012; Commissaris et al., 2014).

Cognitive tasks have been largely overlooked in active workstation research. Studies have shown an improvement in cognition after aerobic exercise (Pesce, 2012), but these studies all investigated post-completion tasks. The current experiment looked at whether continuous, light physical activity affected cognition during the exercise by having participants perform tasks during both the standing and walking conditions.

Selective attention tasks such as the Stroop Color Word Task (Stroop, 1935) have been looked at by Ohlinger et al. (2011) and John et al. (2009) with neither finding a significant difference in performance between walking and sitting conditions. Similar data resulted from this study for attention tasks, which showed a slight improvement in performance but no significant difference between walking and sitting. However, two of the tasks, visual search and time perception, both showed an increase in performance ($p < 0.001$) during the walking condition compared to sitting. This helped support the hypothesis that cognitive tasks would not be negatively affected by the walking condition. Despite research which argues that walking does require attention (Regnaux et al., 2006), the current experiment found that cognitive processes are not negatively affected when paired with light physical activity. Similarly, Hokanson and Burgess (1963) showed that increased physical arousal is associated with an increase in task performance. However, one needs to consider the practical significance of increasing task performance in the laboratory. Since most jobs do not require ever-increasing performance on everyday tasks, this creates a threshold beyond which improved performance does not make sense (Hancock et al., 1989), otherwise known as *satisficing* (Simon, 1965).

Ultimately, given the results of the current experiment and past research, there are some guidelines that should be followed by users of active workstations. When standing, focus should be placed on typing and mousing tasks: emailing, report writing, and file navigation tasks. Walking better supports cognitive tasks: talking on the phone, visual search, and memory tasks. If used in this way, an active workstation could benefit a user greatly by decreasing sedentary behavior, increasing physical activity, and limiting task performance decrement.

Limitations

One limitation of this study is that all subjects were students, which may limit the ability to generalize (because of age differences, experience, etc.) the results to the targeted population of office workers. Another limitation was that each subject was tested under each condition, sequentially, over three hours. This was done to ensure that the subjects completed all of the conditions and to limit the attrition rate multiple sessions would have likely generated. To account for these limitations the tasks were limited to short durations–between two and five minutes in length–in order to limit the potential for any training effects to occur. The order of the tasks was varied between trials, and testing conditions were counterbalanced during the second and third trials between standing and walking. Statistical analysis confirmed that there were no effects of order on the outcome measures.

Conclusion

The results of this study provide insight into how active workstations should be implemented in order to produce the health benefits (e.g. increased physical activity, decreased risk of major health problems like obesity, etc.) associated with decreasing sedentary behavior, while at the same time limiting task performance decrements. This work contributes to the guidance needed for using these systems properly and effectively, suggesting which tasks should be performed while standing (fine motor control tasks e.g. mousing tasks) and walking (cognitive tasks, e.g. attention, memory, visual search). Additionally, the workers' workload should not be overlooked when employing these systems as walking was found to consume a significant amount. However, if these systems are properly used office workers could see a significant decrease in their sedentary behavior without sacrificing performance on their tasks at work.

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