

Effect of Using a Treadmill Workstation on Performance of Simulated Office Work Tasks

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Although using a treadmill workstation may change the sedentary nature of desk jobs, it is unknown if walking while working affects performance on office-work related tasks. **Purpose:** To assess differences between seated and walking conditions on motor skills and cognitive function tests. **Methods:** Eleven males (24.6 ± 3.5 y) and 9 females (27.0 ± 3.9 y) completed a test battery to assess selective attention and processing speed, typing speed, mouse clicking/drag-and-drop speed, and GRE math and reading comprehension. Testing was performed under seated and walking conditions on 2 separate days using a counterbalanced, within subjects design. Participants did not have an acclimation period before the walking condition. **Results:** Paired *t* tests ($P < .05$) revealed that in the seated condition, completion times were shorter for mouse clicking (26.6 ± 3.0 vs. 28.2 ± 2.5 s) and drag-and-drop (40.3 ± 4.2 vs. 43.9 ± 2.5 s) tests, typing speed was greater (40.2 ± 9.1 vs. 36.9 ± 10.2 adjusted words \cdot min⁻¹), and math scores were better (71.4 ± 15.2 vs. $64.3 \pm 13.4\%$). There were no significant differences between conditions in selective attention and processing speed or in reading comprehension. **Conclusion:** Compared with the seated condition, treadmill walking caused a 6% to 11% decrease in measures of fine motor skills and math problem solving, but did not affect selective attention and processing speed or reading comprehension.

Keywords: light-intensity activity, walk-work, NEAT

Currently, two-thirds of American adults are either overweight or obese.¹ Obesity rates are rapidly increasing in most modern and industrialized nations.^{1,2} The obesity epidemic has been attributed to the increased availability of inexpensive energy-dense foods in conjunction with a modern environment that has reduced opportunities to be physically active.² To combat this epidemic, there has been an emphasis on increasing physical activity through structured exercise regimens. More recently, it has been suggested that an increase in nonexercise activity thermogenesis (NEAT) may help control weight.³ In 2003, the U.S. Census bureau estimated that approximately 52.4% of employed Americans use a computer at work.⁴ Because many Americans spend time at work sitting in front of a computer, researchers have identified the work environment as a place to increase NEAT.^{4,5}

The treadmill workstation was first proposed and built twenty years ago by Edelson to reduce inactivity in office workers.⁶⁻⁸ It was touted to solve the hazards of continuous sitting (postural fixity). These hazards included aches and pains, stress, and other illnesses.⁶⁻⁹ Treadmill workstations allow users to alternate between sitting and walking while working during a regular workday. Treadmill workstations consist of a conventional motorized treadmill that slides under a height adjustable sit-to-stand table. A regular office chair allows the user to sit, if they choose.

After briefly disappearing, the treadmill workstation concept was reintroduced as a potential weight loss strategy by Levine and coworkers.⁵ They suggested that if an obese individual walked 2 to 4 hrs/workday at a treadmill workstation, he/she would increase daily energy expenditure by about 500 kcal-day⁻¹.⁵ They estimated that this could translate to a yearly weight loss in the range of 20 to 30 kg.⁵

Although the treadmill workstation seems to have the potential for weight loss, the effects of this approach on work performance still need to be assessed. An individual using a treadmill workstation may need to divide attentional resources between treadmill walking and office work, which might compromise work performance. It remains to be seen if slow walking at a tread-

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mill workstation affects performance in work related variables. The results of such a study would establish the feasibility of the treadmill workstation as an effective strategy for weight control. Thus, the purpose of this study was to determine if walking while working at a treadmill workstation affects selective attention and mental processing speed and the performance of simulated office work tasks involving 1) fine motor movements (typing and mouse movements) and 2) mathematical and verbal reasoning.

Methods

Workstation

The treadmill workstation consisted of a sit-stand table (501-11; Conset A/S, Denmark), height adjustable office chair, treadmill (T1450; Vision Fitness, Lake Mills, WI), and a computer. These components were purchased separately and assembled in the Applied Physiology Laboratory (Dept of Exercise, Sport, and Leisure Studies) at the University of Tennessee. The table used in the current study could be lowered to a minimum height of 76 cm for seated work and raised to a maximum height of 113 cm above the treadmill deck during walking. The recommended heights while performing normal sitting and standing work are 70 to 78 cm and 95 to 115 cm, respectively.¹⁰ The treadmill workstation was constructed in a way that the user could alternate between treadmill walking and sitting by simply stepping off the treadmill, sitting on the chair, and adjusting the table to a desired height by means of an electronic switch. The computer screen was placed on the table surface and could be moved to suit treadmill walking or sitting.

Participants

Eleven male (24.6 ± 3.5 y) and 9 female (27.0 ± 3.9 y) graduate students from the University of Tennessee volunteered to participate in this study. Ability to participate in the study was assessed using a medical history questionnaire. All participants provided written, informed consent. Although all participants were familiar with treadmill walking, none were used to continuous, slow treadmill walking at 1mph or had previously used a treadmill workstation. The experimental protocol was

approved by the University of Tennessee Institutional Review Board. As a safety precaution, a 1-meter lanyard was attached to the participant's clothing that would automatically turn off the treadmill if they moved more than 1 meter away from the treadmill control panel during walking. Height and weight of each participant was measured using a stadiometer and physician's scale, respectively. Participant characteristics are shown in Table 1.

Test Battery

Participants had to complete a test battery comprising of 5 tests to assess selective attention and processing speed, cognitive function and fine motor movement. The paper-and-pencil form of the Stroop Color and Word Test (Stoelting Co., Wood Dale, IL.) was used to measure selective attention and processing speed.¹¹ The Stroop test activates an automatic verbal interference that impedes the task of color naming.¹² This test is valid and reliable in identifying individual differences in the allocation of attentional resources caused by interference.¹³ The test had 3 sections of 100 items each and participants had 45 seconds per section to complete as many items as possible. During testing, participants had to verbally identify each item so that the test administrator could verify if items were being correctly identified. The first section required participants to read the names of colors printed in black ink. The second section had items represented by 4 consecutive X symbols printed in red, blue, or green and participants had to identify the color of the print. Items in the third section were names of colors (*Red*, *Blue*, and *Green*) printed in a color not represented by the word. Participants had to identify the color of the printed word rather than simply read the word. For instance, if an item on the test were the word *Red* printed in green ink, the correct answer to this item would be green. The number of correct items for each section were recorded and used to determine *t*-scores. The method of obtaining *t*-scores is described in the product manual that accompanies the Stroop Color and Word Test.¹¹

Fine motor movement performance was assessed with a typing and 2 computer mouse proficiency tests. These tests were conducted on a Dell OptiPlex GX260 desk top computer with an Intel Pentium 4 processor (2.40 GHz) and 256MB RAM. The Mavis Beacon Teaches Typing 17 (Riverdeep Inc., San Francisco, CA.) computer program was the standard typing exercise for all participants. In this test, participants had to replicate sections of text displayed on the screen. On completion of the assigned paragraphs, typing speed, excluding any errors made, was recorded in adjusted words per minute (AWPM). This software has previously been used in research studies to assess typing speed.^{14,15} Computer mouse proficiency was assessed using a visual basic program. In this test, participants were instructed to perform a mouse clicking and a drag-and-drop task.¹⁶ In the mouse clicking task, the participant had to click on 1 of

Table 1 Physical Characteristics of Participants (N = 20)^a

Characteristic	
Age (y)	26.4 (4.04)
Height (m)	1.69 (0.10)
Weight (kg)	67.05 (15.76)
BMI (kg/m ²)	22.98 (3.44)

^a Data expressed as mean (SD).

25 icons that randomly turned red in color until all icons were clicked. The drag-and-drop task involved dragging and dropping 25 icons 1 at a time (when red) into a larger black box. An icon stayed red until successfully dropped into the box, after which another random icon on the screen turned red. The time taken to complete each task was recorded.

Paper-based graduate record examination (GRE) math and verbal (reading comprehension only) sections were used to assess cognitive function of the participants. These sections were obtained from the official source for GRE review guide (Educational Testing Services) that contain examples of actual GRE tests. The GRE is used to predict academic performance by measuring the basic developed abilities related to success in graduate school.¹⁷ Mathematical reasoning and reading comprehension tests from the GRE have been used in previous research studies examining cognitive function.^{18,19} For the verbal section, each participant was instructed to read a long (600 words) and short paragraph (200 words), and to answer 11 related questions in 18 min. The reading comprehension part of the GRE is designed to measure the ability to analyze, evaluate, and synthesize information. For the math section participants had to answer 30 questions in 30 min. This section of the GRE measures the participant's ability to reason and solve quantitative problems under a time constraint. Scores for both GRE tests were calculated as the total percentage of correct responses from each test.

Study Design

Data collection was conducted at the treadmill workstation during 2 visits separated by 2 days. During their first visit, the study protocol was explained to the participants and they completed the test battery for either the sitting or treadmill walking (with no prior acclimation) condition. The test battery for the remaining condition was completed during the second visit. Participants were allowed to adjust the table to a desired height for both conditions. During the treadmill walking condition, participants underwent testing while walking at 1 mph (27 m·min⁻¹). Participants were allowed to warm up at this speed for a few minutes before the test began. The intensity of level walking at 1 mph is less than 2 METS.²⁵ To avoid a testing effect, 2 different versions of the GRE and typing test paragraphs were used. A counterbalanced, within-subjects design was used to avoid confounding due to order effects.

Statistical Procedures

Statistical analyses were conducted using SPSS version 14 for windows (SPSS, Chicago, IL). The independent variable in this study was the treadmill workstation condition (seated vs. treadmill walking). The dependent variables were scores for the Stroop task (t-scores), typing test (AWPM), mouse clicking and drag-and-drop

tests (completion time), and GRE math and reading comprehension (percentage of correct answers) tests. Test results are presented as means \pm standard deviations. Paired samples *t* tests were used to examine differences between test results from treadmill walking and the sitting conditions. Repeated-measures ANOVAs on test versions were performed to determine if GRE test versions had a confounding effect on the results from the 2 conditions. Statistical significance for all analyses was set at $P < .05$.

Results

Paired samples *t* tests showed significant differences between the 2 conditions on typing, mouse proficiency, and GRE math test scores. In the sitting condition, participants displayed better scores on the typing ($t_{19} = -3.161, P = .005$), recorded lower completion time on the mouse clicking ($t_{19} = 2.747, P = .013$) and drag-and-drop tests ($t_{19} = 3.839, P = .001$), and scored higher on the mathematical reasoning test ($t_{19} = -2.169, P = .017$). Figures 1, 2, and 3 illustrate performances on the Stroop and typing test, mouse proficiency tests, and cognitive tests, respectively. Mouse clicking and drag-and-drop scores (in seconds) for the walking condition were lower by 8% and 6%, respectively. Typing (AWPM) and math scores for the sitting condition were 9% and 11% greater than scores for the walking condition, respectively. There were no significant differences ($P < .05$) between the walking and sitting conditions for the Stroop and reading comprehension tests. However, repeated-measures ANOVA showed a significant condition \times version interaction for reading comprehension ($P < .05$). In other words, the group that took version 1 while walking and version 2 while sitting scored better in the sitting condition, and the group that took version 2 while walking and version 1 while sitting scored better in the walking condition. However, there was no overall significant difference in reading comprehension between the sitting and walking conditions.

Discussion

Test Results

The results of the current study indicate that walking while working decreases scores on tests of typing and mouse proficiency, and math solving ability by approximately 6 to 11%. This may be because the added task of walking puts an increased load on both mental processing and motor control.²⁰⁻²³ An increased load causes interference in 1 or both tasks, thereby lowering task performance.²⁰

Significantly lower ($P < .05$) performances on fine motor movement tests during the walking condition may have resulted from the increased complexity of performing multiple motor tasks (walking and typing/mouse tasks) that require a more complex interaction

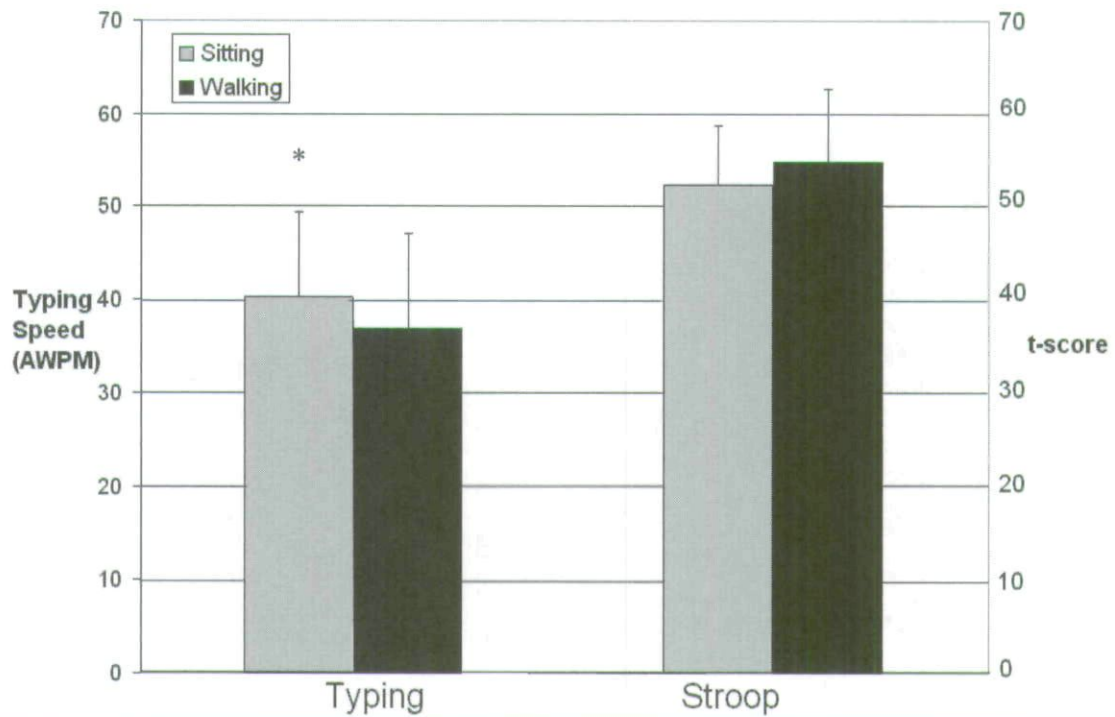


Figure 1 — Mean scores and standard deviations on typing and Stroop tests for walking and sitting conditions (N = 20). * Significantly different from each other ($P < .05$).

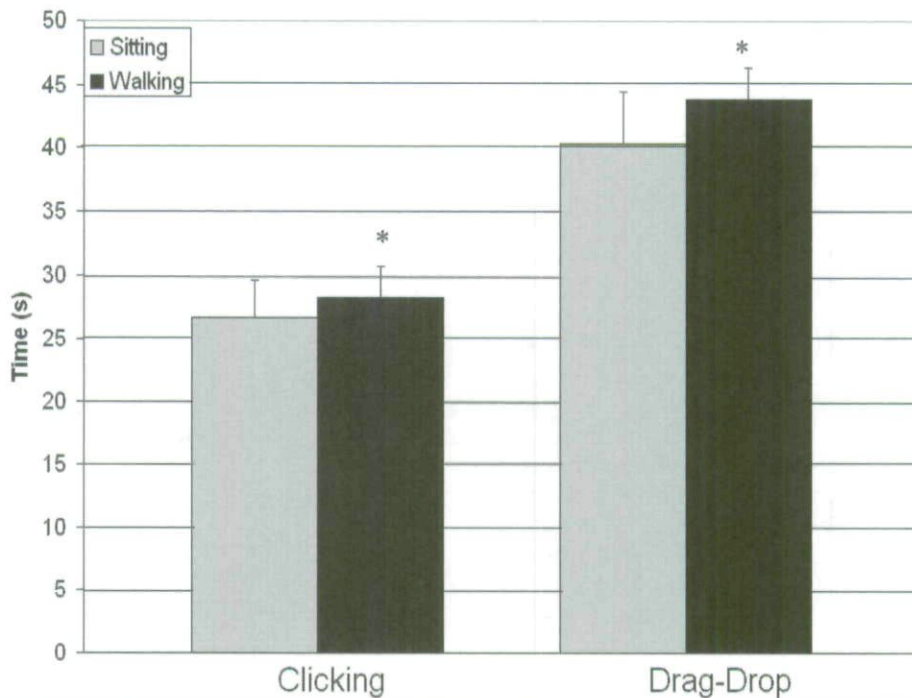


Figure 2 — Mean scores and standard deviations on mouse clicking and drag-and-drop tests for walking and sitting conditions (N = 20). * Significantly different from each other ($P < .05$).

with cognitive abilities, and increased recruitment of attentional resources.^{21,22} Similarly, performing a cognitive function like math problem solving and treadmill walking simultaneously may have increased complexity

and thereby placed a higher than normal demand on attentional resources. This may have resulted in lower scores on the mathematical reasoning tests during the walking condition. Research by Giorno et al²⁴ showed

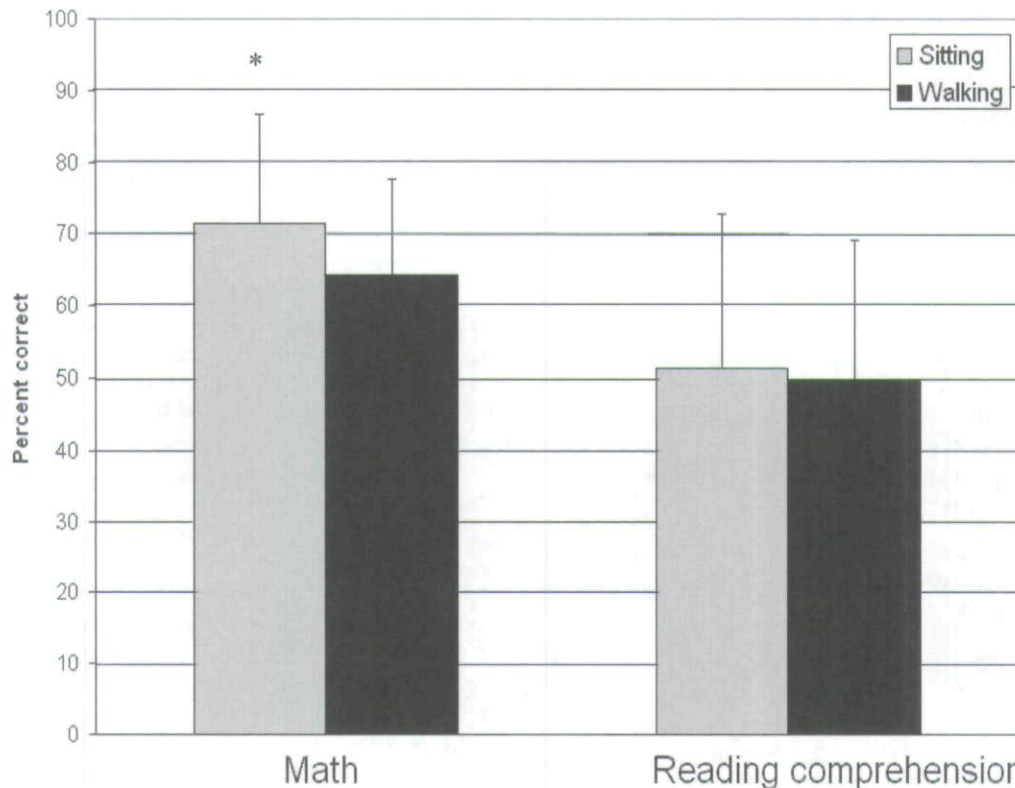


Figure 3 — Mean scores and standard deviations on GRE math and reading comprehension tests for walking and sitting conditions ($N = 20$). * Significantly different from each other ($P < .05$).

significantly lower performances ($P < .05$) on a finger tapping task and a cognitive test during submaximal exercise (75% of ventilatory threshold) as compared with performances in a sitting condition.²⁴ Although the exercise intensity in the study by Giorno et al was much higher than the current study, a similar trend of decreased performance during dual task performance was observed in both studies.²⁵

Findings on the typing tests from the current study were different from those by Edelson and Danoff.⁸ They found no significant difference in typing performances between walking and sitting while working at a treadmill workstation.⁸ In contrast to this finding, the current study determined that typing speed decreased slightly (3.3 ± 4.7 AWPM) while walking. This discrepancy may have resulted from the fact that participants in Edelson and Danoff's study had an average seated typing speed of 61 AWPM in comparison with only 40 AWPM in participants from the current study.⁸ The average typing speed of the current participants was similar to the average speed (40 AWPM) of 3475 participants from Ostrach's study.²⁶ Results from Ostrach would classify participants tested by Edelson and Danoff in the 2nd decile and the current participants in the 5th decile.²⁶ Therefore, the difference between findings from Edelson and Danoff and the current study may have resulted from the fact that participants in the former study were more experienced typists than those

in the current study. In addition, Edelson and Danoff examined only 5 participants and their study may have lacked the statistical power required to show a significant difference.

Unlike fine motor movement and GRE math tests, results from the Stroop tests were not significantly different between walking and sitting conditions. During the Stroop test, participants use their working memory to resolve a mental conflict between word reading and color naming.^{12,27} In the walking condition, participants also had to simultaneously process the task of walking. Findings from the current study were similar to those by Grabiner and Troy who did not report a significant difference ($P = .052$) in Stroop test results between a stationary condition (standing) and treadmill walking.²⁰ However, they reported a significant decrease in step width variability during treadmill walking while performing the Stroop test.²⁰ They concluded that voluntary gait changes occur to compensate for the reduced visual resources allocated to walking while performing the Stroop test.²⁰ The current study did not assess step width variability. In general, it can be said that walking while performing tasks that invoke a mental load similar to the Stroop test, does not affect an individual's performance on the mental task.

Like the Stroop test, reading comprehension scores in the sitting condition were not significantly different ($P < .05$) than scores in the walking condition. These

results are in contrast to those of Barnard, Yi, Jacko, and Sears where reading comprehension scores for sitting were significantly higher ($P < .01$) than those for walking.²⁸ Unlike Barnard et al who reported a 10% difference between scores, reading comprehension scores while sitting were only 4% higher than treadmill walking in the current study. This difference may be attributable to the fact that participants from Barnard et al walked on a narrow course that meandered around a room as compared with the simpler task of treadmill walking in the current study. In addition, the device used by Barnard et al was a personal digital assistant (PDA) and had a much smaller screen as compared with the computer monitor in the current study.²⁸ In summary, reading comprehension may not place as high a demand on attentional resources as other tasks, and thus is not affected by treadmill walking.

Practical Implications of Lowered Performance

Although performance during the walking condition was statistically lower for the typing, mouse proficiency, and math tests, this section of the paper attempts to examine how these results could potentially impact real-life work productivity. In this study, average typing speed decreased from 40.2 while sitting to 36.9 AWPM while walking. According to Ostrach, the average typing speed lies between 38 and 43 AWPM.²⁸ It can be speculated that, because the reduced typing speed during the walking condition falls out of the average typing speed by just 1 AWPM, there may be a marginal impact on typing while walking and working in an office setting. To substantiate the previous argument, we could consider the example of emailing, which is a popular form of electronic communication.²⁹ A study that examined e-mail communication between physicians and their patients showed that patient emails and physician replies averaged 139 and 39 words, respectively.²⁹ If we compute the time taken to compose an e-mail by these individuals based on average typing speeds from Ostrach's study (sitting: 40 AWPM) and the current study (walking: 36.9 AWPM), patients and physicians using a treadmill workstation would take only 17.5 and 4.9 s longer to compose an e-mail, respectively. In addition, according to the International Organization of Standardization (ISO) ergonomic standard for computer visual display terminals, if a standard keyboard is replaced with a different kind that may cause a decrease in typing speed, the speed obtained using the new one must lie within 0.75 standard deviations of the speed for the standard keyboard to be acceptable.³⁰ Although we did not compare different keyboards in our study, we can apply ISO standards to our results because we induced an experimental condition that decreased typing speed. Typing speed during the experimental walking condition (36.9 ± 10.2 AWPM) was within the acceptable range (33.4 to 47 AWPM) as per ISO specifications.

The use of a computer mouse depends mainly on the type of job being performed. In this study we examined the effect of walking while working on clicking and drag-and-drop tasks only. A previous study examining computer mouse use in office workers showed that an employee moves and clicks the mouse approximately 78 times per hour.³¹ In the current study, time taken to move the mouse and click an item took 1.06 and 1.12 s while sitting and walking, respectively. Therefore, moving the mouse and clicking 78 items in an hour while walking and working would require only 4.68 s more than sitting, which may not have a substantial effect on overall work productivity. In general, the task of dragging-and-dropping items using a mouse at work is less frequent than clicking.

The third test that showed significantly different results between sitting and walking conditions was the GRE math test. To accommodate errors in the measurement process, Educational Testing Services defines a "meaningful difference between scores" as a value greater than 2 times the standard error of measurement (SEM) of score differences. In the current study, the difference between sitting and standing conditions for the math test was 2.48 times the calculated SEM of score differences and thus meaningful.³² However, the margin that renders the walking GRE math score to be meaningfully different from that obtained while sitting is very small. In other words, the score obtained while walking (64.3%) would not have been meaningfully different from the score obtained while sitting (71.4%) if it was between 65.6 and 77%.

The differences between scores for the sitting and walking conditions on the typing, mouse proficiency, and the GRE math tests could be reduced through acclimation.^{33,34} In light of the potential benefits of using a treadmill workstation, the benefits may outweigh the differences observed.

Restoring Energy Balance

Current data indicate that in the past forty years, there has been an increase in the average American's caloric consumption and a concurrent decrease in energy expenditure.^{35,36} As a result, the average American adult gains 1.8 to 2 pounds/year.³⁷ Levine and Miller suggested that walking while working at a treadmill workstation increases energy expenditure by approximately 165% in obese individuals as compared with sitting at a desk.⁵ They speculate that the treadmill workstation may be effective in preventing weight gain or lowering obesity rates in office workers.

Hazards of Sitting

Occupations involving continuous seated work result in increased musculoskeletal discomfort.³⁸ Individuals who sit for more than 95% of time at work experienced greater musculoskeletal discomfort than those who were able to vary their posture.³⁹ In response to a subjective

assessment of musculoskeletal discomfort, users of the treadmill workstation report that walking while working helped reduce back problems associated with continuous sitting.⁴⁰ In addition to musculoskeletal discomfort, sedentary behaviors like continuous sitting also affect the body at a molecular level. Hamilton, Hamilton, and Zderic proposed that prolonged hours of sitting may upregulate specific molecular, physiologic, and biochemical responses (also known as *inactivity physiology*) that could lead to metabolic disorders.⁴¹ A specific example of molecular adaptations to reduced low-intensity activity is the transcription of an inhibitory gene that induces LPL suppression through a posttranslational mechanism.⁴¹ Hamilton et al state that inactivity (sitting) and low nonexercise activity may produce serious health problems that cannot be explained by exercise deficiency alone.⁴¹ In other words, maintaining higher levels of low-intensity activity independent of the recommended moderate-vigorous physical activity can lower several metabolic risk factors.⁴¹

Strengths and Limitations

A limitation of this study is that it was not conducted in a proper office setting. In addition, the participants in this study were graduate students and not actual employed office workers. The results of this study may not be comparable to results from an office setting because the duration of a single testing session (60 min) was less than the recommended duration of 2 to 4 hrs/day. More importantly, the participants may not have had sufficient time to acclimatize to walking and working. Acclimation may reduce or eliminate the marginal lowering of work performance observed initially. Research examining interference due to dual task performance suggests that acclimating to performing dual tasks can reduce or even eliminate interference, thereby resulting in improved task performance.^{33,34} In addition, other factors that may potentially affect work performance are not discussed in this study. One such factor could be variability in distance from the area of work due to selected conditions (sitting and walking). Assessing the effect of all potential factors that may affect work performance was beyond the scope of this study.

On the other hand, the current study is the only of its kind to have examined the impact of using a treadmill workstation on the performance of tasks that simulate office work. The selected tasks involved cognitive and motor skills that are a requirement in today's work environment. The current study also established that walking while working did not greatly affect work performance.

Conclusion

The treadmill workstation aims to replace 2 to 4 hours of sitting at work with low-intensity physical activity that may help obese office workers achieve a negative

energy balance and reduce obesity related costs.^{5,42} Using a treadmill workstation could also attenuate musculoskeletal discomfort, reduce metabolic risk factors associated with continuous sitting, and lower stress levels.^{8,41} The current study compared the effects of using a treadmill workstation on simulated office work tasks. Walking while working was associated with a minor 6 to 11% decrease in math problem solving, mousing, and typing performance. It is possible that this decrease in performance could be eliminated through acclimation to walking while working. It is imperative to investigate work performance in a proper office setting after participants are used to walking and working for at least 2 to 3 hrs/day. Future studies should examine if using the treadmill workstation helps lower body weight, reduce fat mass, and lower employee health care costs. If these benefits can be shown, it may be possible to convince employers that the benefits of treadmill workstations justify the costs.

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