Effect of Standing or Walking at a Workstation on Cognitive Function: A Randomized Counterbalanced Trial

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Objective: In the present study, we examined the effect of working while seated, while standing, or while walking on measures of short-term memory, working memory, selective and sustained attention, and information-processing speed.

Background: The advent of computer-based technology has revolutionized the adult workplace, such that average adult full-time employees spend the majority of their working day seated. Prolonged sitting is associated with increasing obesity and chronic health conditions in children and adults. One possible intervention to reduce the negative health impacts of the modern office environment involves modifying the workplace to increase incidental activity and exercise during the workday. Although modifications, such as sit-stand desks, have been shown to improve physiological function, there is mixed information regarding the impact of such office modification on individual cognitive performance and thereby the efficiency of the work environment.

Method: In a fully counterbalanced randomized control trial, we assessed the cognitive performance of 45 undergraduate students for up to a 1-hr period in each condition.

Results: The results indicate that there is no significant change in the measures used to assess cognitive performance associated with working while seated, while standing, or while walking at low intensity.

Conclusion: These results indicate that cognitive performance is not degraded with short-term use of alternate workstations.

Keywords: sitting, standing, walking, cognitive function, randomized control trial

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INTRODUCTION

Individuals who spend a large part of their day sitting down are more likely to be overweight or obese, even if they meet national guidelines for physical activity during their leisure time (Brown, Miller, & Miller, 2003; Mummery, Schofield, Steele, Eakin, & Brown, 2005). Overweight and obese adults have a significantly elevated risk of chronic and severe health conditions in later adulthood, including type 2 diabetes, cardiovascular disease, ischemic stroke, and several forms of cancer (National Task Force on the Prevention and Treatment of Obesity, 2000). Negative health consequences are also associated with prolonged time spent seated, including increased musculoskeletal pain, particularly in the shoulders, neck, and lower back (VicHealth, 2012). This musculoskeletal pain is associated with reduced work productivity (Blyth, March, Nicholas, & Cousins, 2003), increased absenteeism, and impaired quality of life (Rasmussen, Holtermann, Mortensen, & Jorgensen, 2013).

In light of the negative consequences of sedentary behavior on physical health, there is increasing interest in exploring the potential benefits of reducing the amount of time per day individuals are engaged in sedentary activities (Cooley & Pedersen, 2013). The single major contributor to the increased proportion of daily living spent engaged in sedentary activity is the workplace, with the increased prevalence of work tasks being performed seated for extended periods. Reducing the proportion of time spent seated in the workplace may reduce the risk of developing chronic health conditions later in life. However, it remains unclear as to whether body position (i.e., standing or sitting) results in a change in cognitive function or work productivity.

Increased physical activity is associated with improved physical health and cognitive function across the life span. Being physically active is associated with an increase in the volume of brain regions associated with some cognitive functions (Chaddock et al., 2010), increases in event-related potentials that are associated with cognitive function (Hillman, Buck, Themanson, Pontifex, & Castelli, 2009), and changes in cortical activation (Davis et al., 2011). In a review of existing literature, Guiney and Machado (2013) report that in adult populations, higher levels of physical activity are associated with improved task switching, selective attention, inhibitory control, and working memory. Further, improvements to information-processing speed (Barella, Etnier, & Yu-Kai, 2010) and verbal learning and memory (Etnier, Labban, Piepmeier, Davis, & Henning, 2014) have been found to occur immediately after cessation of physical activity. Therefore, existing research suggests that physical activity is associated with structural brain changes that may trigger a secondary improvement in cognitive functions associated within those brain regions.

Due to the emerging evidence that prolonged sitting in the workplace may result in increased rates of obesity and other chronic health conditions, along with the findings that recreational physical activity outside of work hours does not offset these negative effects of prolonged sitting, approaches to reducing sedentary behavior, such as prolonged sitting, in the workplace are being developed (Mainsbridge, Cooley, Fraser, & Pedersen, 2014). One method of reducing sedentary behavior has been to install sit-stand workstations. These workstations allow users to adjust the height of their desk throughout the workday to either a sitting height or a standing height. Other models can be adjusted to allow individuals to walk on a treadmill or ride an exercise bike while continuing their normal work (active workstations). These desks have been shown to reduce sitting time as well as increase general levels of physical activity in the workplace (Grunseit, Chau, van der Ploeg, & Bauman, 2013).

Furthermore, participants in studies on the use of sit-stand workstations generally report satisfaction with the desks and enjoy being able to change their postural position throughout the workday (Alkhajah et al., 2012). Moreover, sit-stand workstations have been shown to reduce musculoskeletal complaints (Husemann, Von Mach, Borsotto, Zepf, & Scharnbacher, 2009; Pronk, Katz, Lowry, & Payfer, 2012), improve the overall mood of workers (Pronk et al., 2012), promote faster metabolism of blood glucose following a meal (Buckley, Mellor, Morris, & Joseph, 2013), and lead to greater movement in the workplace (Grunseit et al., 2013; Vink, Konijn, Jongejan, & Berger, 2009). Currently, research indicates that sit-stand workstations may be a viable solution to reducing the incidence of obesity and chronic health conditions in an increasing sedentary workplace.

Despite recent interest surrounding sit-stand desks and the physical health benefits associated with reduced sitting time, research into the possible cognitive consequences associated with using sit-stand and active workstations remains limited. Ohlinger, Horn, Berg, and Cox (2011) investigated the effect of sit-stand desks on cognition, attention, and motor skills in 50 healthy university employees. Participants completed three tests assessing verbal short-term memory span (Auditory Consonant Trigram Test), selective attention (Stroop Colour Word Test), and one motor task (finger-tapping speed) while sitting, standing, and walking slowly on a treadmill during a single 75-min session. The results of this study revealed no significant difference in performance on the cognitive tasks between the three postural positions; however, there was a slight decrease in performance on the motor task in the walking condition compared to the sitting and standing conditions, which the researchers attributed to attentional interference. This notion of a performance decrement under dual-task conditions is consistent with existing literature; however, such effects are typically modality specific (e.g., performing a motor task while engaging in a second motor activity). Other studies report no dual task impairment when office workers perform a data entry task while standing (Husemann et al., 2009), suggesting that the modality properties of the two tasks may have greater impact than performing two tasks at the same time.

In another study, Ebara et al. (2008) found that participants who completed an English translation task using a sit-stand workstation maintained their level of physiological arousal for the duration of the task, compared to those who sat on a standard chair or sat on an elevated chair. They also found that task performance remained steadily high in the sit-stand condition but declined over time in the two sitting conditions. This finding suggests that there is an increase in physiological arousal when standing compared to sitting and that this increase in arousal can lead to more consistent task performance over a long period.

The study by Ebara et al. (2008), in conjunction with the evidence supporting the relationship between physical activity and cognitive function, suggests that standing while engaging in normal work should lead to improvements in cognitive function. However, as Ohlinger et al. (2011) report, undertaking physical activity (such as walking on a treadmill) while performing a simple finger-tapping task may lead to a decrement in performance as a result of interference. In a recent study, Ben-Ner, Hamann, Koepp, Manohar, and Levine (2014) examined self-reported and supervisor-reported observations of worker performance in workers who used a treadmill workstation compared to workers who remained sitting. Following an initial decline in reported work performance, there was a subsequent increase in performance to a level above that of sitting employees (Ben-Ner et al., 2014).

Although these studies suggest that movement-based workstations (e.g., treadmill desks) may decrease work efficiency in the short term, there are methodological concerns apparent in these studies. The use of self- and other-subjective experiences of work performance has questionable validity. That Ohlinger et al. (2011) infer that a performance decrement on finger-tapping speed while walking was indicative of attentional interference fails to acknowledge that this effect may instead be a result of synchronization of motor phases, an effect widely observed in simple motor tasks performed ipsilaterally with a hand and foot (Baldissera & Esposti, 2005; Fujiyama, Garry, Levin, Swinnen, & Summers, 2009; Fujiyama, Hinder, Garry, & Summers, 2013; Fujiyama, Hinder, Schmidt, Garry, & Summers, 2012; Hiraga, Garry, Carson, & Summers, 2009; Muzii, Warburg, & Gentile, 1984; Repp, 2005). Hence, the slowing of tapping speed while walking observed by Ohlinger et al. may instead reflect in-phase coupling of tapping speed to walking speed and not an attentional interference effect.

The aim of this study was to investigate the possible cognitive consequences of sitting, static standing (using a standing desk without movement), and walking (low-intensity walking while working at a standing desk) in an undergraduate student population. This study utilizes a design similar to that of Ohlinger et al. (2011) but employs the use of a visuomotor information-processing speed task (Digit Symbol Coding) that is not associated with phasic coupling with motor movements of the foot or legs. The present study also includes a variety of tests. In addition to measures of verbal short-term memory and selective attention (as used by Ohlinger et al., 2011), we include measures of verbal working-memory capacity, visual information-processing speed, and sustained attention. This method enables examination of the effect of sitting, standing, and walking on a wider range of cognitive functions. It was hypothesized that significant improvements across all cognitive functions assessed (working memory, sustained attention, information-processing speed, short-term memory, and selective attention) would occur while participants were assessed in a static standing condition as opposed to in a seated or walking condition. The hypothesized performance differences are expected to reflect cognitive enhancement in the static standing condition as well as a cognitive decrement arising from dual-task interference in the walking condition.

METHOD

Participants

Participants were 45 young adult undergraduate students from the University of Tasmania (32 female, 13 male). Exclusion criteria included pregnancy or health conditions, such as heart disease, epilepsy, or chronic back pain, as these conditions may be aggravated by prolonged sitting, standing, or walking. The sample had an average age of 22.67 years (SD = 6.27 years), were of average to high-average intelligence (M = 104.04, SD = 6.36), and reported low caffeine use (M = 0.80, SD = 1.02 servings per day), with one participant reporting cigarette use. A significant difference in Hospital Anxiety and Depression Scale (HADS; Snaith & Zigmond, 1994) depression scores was identified between conditions; however, these scores remain in the nonclinical range (<8), indicating that participants did not display any increase in clinically significant levels of depression. As depressed or anxious mood states negatively affect cognitive test performance, the absence of clinically significant mood disturbance in the sample indicates that mood is unlikely to contribute to any differences in cognitive performance. Participants were randomly assigned to one of six counterbalanced condition orders.

Materials

Two sit-stand workstations were used in this study. The first was an active workstation with a treadmill attached to the base. The treadmill was set at a slow speed (between 1 and 3 km/hr), depending on participants' comfort level. The second was a sit-stand workstation that could be adjusted electronically to either a sitting or a standing height. Both workstations were adjusted for an ergonomically correct position for each participant (90° elbow flexion and 0° wrist extension/flexion when typing on a keyboard).

The test battery included two screening tests and six cognitive assessments (see Table 1). All tests were administered and scored according to standardized instructions.

Procedures

Participants provided fully informed consent for participation in this study. The project was approved by the Human Research Ethics Committee (Tasmania) Network in accordance with the Australian National Health and Medical Research Council ethical guidelines. Participants were randomly assigned to one of six counterbalanced order conditions (Table 2) to minimize the effects of postural position order and fatigue on test results.

At the commencement of each session, the height of the desk and, when relevant, the treadmill speed, were adjusted to suit each participant's level of comfort. Participants attended three sessions in a quiet laboratory environment, each occurring at the same time of day, spaced at 7-day intervals. In the first session, participants completed the demographic questionnaire screening tests, followed by the complete cognitive assessment battery (Table 1) while the participant was using the desk in the assigned position for each condition. In Sessions 2 and 3, participants completed all tests in the cognitive assessment battery with the exception of the Wechsler Test of Adult Reading (Psychological Corporation, 2001). Completion of the cognitive test battery took less than 60 min with the participant undertaking all assessment under the positional parameters specific to each condition (Table 2).

Statistical Methods

To test the hypothesis against each of the nine cognitive variables used, a series of one-way repeated-measures ANOVAs with Bonferroni-adjusted alpha levels were conducted with $p <$ .005 required to attain significance.

RESULTS

One-way repeated-measures ANOVAs for all hypotheses returned nonsignificant results with small effect sizes (Table 3), indicating no change in performance on cognitive tests associated with alterations to work position for up to 1-hr periods.

DISCUSSION

The results of the present study did not support the hypothesis. There was no detectable change in the chosen measures of short-term memory, working memory, attention (selective or sustained), or information-processing speed when participants worked at a desk in a sitting position, in a standing position, or while walking on a treadmill. Furthermore, the effect sizes (η_p^2) for each of these cognitive functions were very small, ranging from .001 to .05, indicating that the magnitude of the effect observed was below that required for a meaningful change in function. The effect sizes in the present study are comparable to the effect sizes found in a similar study by Ohlinger et al. (2011). Further, the results of the present study are consistent

TABLE 1: Cognitive Test Battery and Test Order

Test	Function Assessed	Description of Measure
Screening		
Wechsler Test of Adult Reading (WTAR; Psychological Corporation, 2001)	Estimated intellectual capacity	The WTAR consists of 50 words that have an atypical grapheme-to-phoneme translation. The number of words correctly pronounced provides a stable and reliable estimate of intellectual capacity, with the score used being a conversion from raw score to a full-scale intelligence quotient (FSIQ; $M = 100$, $SD = 15$).
Hospital Anxiety and Depression Scale (HADS; Snaith & Zigmond, 1994)	Clinical symptoms of anxiety and depression	The HADS was used at the beginning of each test session. The HADS is a 14-item scale with seven items relating to depression (HADSd) and seven items relating to anxiety (HADSa) experienced in the previous week. Scores (HADSa and HADSd) range from 0 to 21, with scores >10 indicating a potential clinically significant mood disorder.
Cognitive assessment		
Digit Span forward (DSf; WAIS-III; Wechsler, 1997)	Verbal short-term memory capacity	Participants repeat a series of numbers presented to them aurally by examiner. Digits are presented at 1-s intervals with the sequence length increasing progressively from two digits to a maximum of nine digits. The test is discontinued if a participant fails to correctly repeat two trials of the same length. DSf raw score was calculated by summing the number of trials answered correctly in a range of 0 to 16.
Digit Span backward (DSb; WAIS-III; Wechsler, 1997)	Verbal working-memory capacity	Participants repeat a series of numbers in the reverse order to that presented aurally by examiner. Digits are presented at 1-s intervals with the sequence length increasing progressively from two digits to a maximum of eight digits. The test is discontinued if a participant fails to correctly repeat two trials of the same length. DSb raw score was calculated by summing the number of trials answered correctly in a range of 0 to 14.
Digit Symbol Coding subtest (DSC; WAIS-III; Wechsler, 1997)	Visuomotor speed and learning	The DSC task requires participants to copy symbols paired with the numbers 1 to 9. The correct pair is provided on a key visible to the participant at all times. The number of correct symbol substitutions made in a time limit of 120 s is the raw score for the DSC, range 0 to 133.
Letter Number Sequencing subtest (LNS; WAIS-III; Wechsler, 1997)	Verbal working-memory capacity and attention	Participants repeat a series of aurally presented letters and numbers to the participant. The participant is required to repeat the sequence such that he or she says the numbers in ascending order and then the letters in alphabetical order. The sequence length of letters and numbers increases progressively from two to a maximum of eight, with three trials at each sequence length. The task is discontinued when a participant fails to correctly repeat three trials at a single sequence length. The raw score was calculated by summing the number of trials answered correctly with a range of 0 to 21.

(continued)

TABLE 1: (continued)

Test	Function Assessed	Description of Measure
Stroop Colour Word Test, Victoria Version (Strauss, Sherman, & Spreen, 2006)	Verbal selective attention	This test required participants to name on three different trials the colors of dots, neutral words, and color words. Each trial comprises 24 items printed in blue-, red-, yellow-, and green-colored ink. The third trial (conflictual naming) is the key trial of interest and required participants to say the color of the ink of a color word where the ink color and color word are incongruent (e.g., the word *blue* printed in red ink, requiring the participant to respond, "Red"). Time to complete each trial and number of errors made were recorded. Participants were told of any error made at the time of making the error and were instructed to correct the error before continuing; hence errors made increased time to completion. Parallel versions of the Stroop test were used across test sessions.
Choice Reaction Time (CRT)	Visual information-processing speed	Participants were required to use the *Z, X*, comma, and question-mark keys on a standard QWERTY keyboard. These keys corresponded to the numbers 1, 2, 3, and 4, respectively. When these numbers were displayed on the screen, participants were required to press the corresponding key as quickly as possible. Participants completed one practice trial of 10 presentations, followed by four test trials each comprising a maximum of 50 correct responses (total of 200 correct responses). The time taken to press the corresponding key (CRTt) and the accuracy of the response (CRTp) was recorded by the computer program. The average CRTt and average CRTp over the 200 correct presentation trials for each participant was calculated for analysis.
Paced Auditory Serial Addition Task (PASAT; Strauss et al., 2006)	Sustained attention	Inquisit PASAT is a computer-based test in which participants listen to an aurally presented series of numbers ranging from 1 to 9. Participants then serially add numbers together so that each number is added to the one presented immediately before it. Participants are then required to select the correct number on the computer screen (e.g., if 5 and 7 are presented, participant responds with "12"; if next number is 3, participant responds with "10"). Participants were provided with headphones in all three conditions to ensure that they could hear the numbers clearly. A practice trial was initially conducted to ensure participants understood the task. This practice was followed by four test trials. The length of time between each number being presented reduces with each trial. The percentage correct on the final trial was used as the dependent variable, as this value indicated the participant's level of attention after a number of trials had occurred. The PASAT is a reliable measure of sustained attention in average to above-average populations.

Note. WAIS-III = Wechsler Adult Intelligence Scale (3rd ed.).

TABLE 2: Counterbalanced Order of Experimental Conditions

	Condition		
Order	Week 1	Week 2	Week 3
1	Sit	Stand	Walk
2	Stand	Walk	Sit
3	Walk	Sit	Stand
4	Sit	Walk	Stand
5	Stand	Sit	Walk
6	Walk	Stand	Sit

TABLE 3: Test Means (and Standard Deviations) for Each Condition and Inferential Statistics

	Condition						
Test	Sit	Stand	Walk	*F*	*p*	Effect Size (η_p^2)	Pairwise Comparisons
HADS anxiety	5.16 (3.11)	5.80 (2.88)	5.51 (3.53)	1.40	.251	.03	
HADS depression	2.38 (2.40)	2.31 (3.31)	1.84 (2.28)	3.90	.024	.08	Sit > Walk; Stand > Walk
LNS	11.49 (2.35)	11.96 (2.30)	11.47 (2.55)	2.05	.14	.05	
CRT time (milliseconds)	455.13 (47.36)	453.36 (45.60)	466.16 (60.44)	1.76	.18	.04	
CRT accuracy (%)	91.79 (4.87)	91.69 (4.63)	91.56 (4.75)	0.08	.93	.002	
PASAT (% correct)	37.76 (15.23)	38.22 (13.79)	37.45 (14.83)	0.06	.95	.001	
DSf	11.40 (2.24)	11.36 (2.09)	11.73 (2.20)	1.58	.21	.04	
DSb	7.22 (1.98)	7.11 (2.50)	7.28 (2.56)	0.20	.82	.004	
DSC	91.60 (14.99)	91.91 (16.59)	88.91 (15.46)	1.34	.27	.03	
Stroop time (seconds)	17.92 (5.09)	18.09 (5.88)	17.39 (5.94)	0.89	.42	.02	
Stroop errors	0.49 (0.69)	0.58 (0.84)	0.38 (0.68)	1.07	.35	.02	

Note. HADS = Hospital Anxiety and Depression Scale; LNS = Letter Number Sequencing; CRT = Choice Reaction Time; PASAT = Paced Auditory Serial Addition Task; DSf = Digit Span forward; DSb = Digit Span backward; DSC = Digit Symbol Coding; Stroop = Stroop Incongruent trial.

with those of Ohlinger et al., with no detectable difference in short-term memory span or selective attention detected across conditions. These results add support to previous research reporting no detectable change in cognitive function in young adults who use a sit-stand or active workstation for up to 1 hr in duration.

Previous research suggests that cognitive function is enhanced when individuals work in a standing as opposed to a seated position (Ebara et al., 2008). Other research suggests that increased levels of physical activity are associated with improvements to cognitive functions, such as task switching, selective attention, inhibitory control, and working memory (Guiney & Machado, 2013) and that cognitive function improves immediately following cessation of physical activity (Barella et al., 2010; Etnier et al., 2014). Somewhat surprisingly, the results of the present study identify no detectable improvement to cognitive performance when participants worked while standing or walking compared to when they were seated. This finding is interesting as it indicates that working while walking at low intensity (1–3 km/hr) did not trigger a dual-task interference effect resulting in performance decrements on tasks requiring rapid fine-motor control with the hands, such as tests of information-processing speed and attention utilized in the present study (Choice Reaction Time task, Digit Symbol Coding).

Participants in previous studies linking physical activity to cognitive function engaged in physical activity over a period of weeks or months (Davis et al., 2011; Kamijo et al., 2011). Other studies demonstrate that although acute improvements to cognitive function may follow physical activity, a single bout of physical activity does not necessarily lead to long-term cognitive change; rather, activity over a long period may be required to effect a change in cognitive performance (Barella et al., 2010; Etnier et al., 2014). Therefore, it is possible that the duration of physical activity in the present study (<60 min walking) was of insufficient duration to result in improved cognitive performance; however, the results of the present study indicate that walking while working has no acute detrimental effect on cognitive performance. In light of this finding, further research on the potential impact of extended use of sit-stand and active workstations on cognitive performance is needed.

The present study involved healthy, educated young adults with no chronic health conditions. Examination of the estimated intellectual capacity and use of caffeine or nicotine indicates that baseline cognitive ability, caffeine intake, and nicotine use are unlikely to confound the results of the analysis. Previous research indicates that adults with lower levels of cognitive function or those suffering from chronic health disorders (e.g., musculoskeletal conditions associated with positional pain or discomfort) may experience a greater enhancement of cognitive functioning following the introduction of physical activity (Anderson-Hanley, Arciero, Westen, Nimon, & Zimmerman, 2012; de Frias & Dixon, 2014; Evers, Klusmann, Schwarzer, & Heuser, 2011). Adults in full-time predominantly sedentary employment are more likely to be older and less physically fit on average than the sample used in this study. Therefore, in a representative sample of office-based employees, the potential of improved cognitive performance following use of a wokstation while engaged in low-level physical activity is greater.

The results of the present study utilizing a fully counterbalanced within-subjects design detected no change in cognitive function observed in healthy younger adults who work while sitting, standing, or walking. This finding has important implications for workplaces and educational facilities that are seeking to implement sit-stand or active workstations. The results of our study suggest that staff and students can utilize sit-stand and active workstations without an acute change in cognitive performance and gain the demonstrated physical health benefits associated with them.

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KEY POINTS

- Prolonged sitting is associated with increasing chronic health conditions.
- Sit-stand desks are a recent modification to the modern office environment designed to increase incidental activity and exercise during the workday.
- In a fully counterbalanced randomized control trial, we found no evidence of significant change in cognitive performance associated with working while seated, standing, or walking at low intensity.

REFERENCES

Alkhajah, T., Reeves, M., Eakin, E., Winkler, E., Owen, J., & Healy, G. (2012). Sit-stand workstations: A pilot intervention to reduce office sitting time. *American Journal of Preventative Medicine*, *43*, 298–303. doi:10.1016/j.amepre.2012.05.027

Anderson-Hanley, C., Arciero, P. J., Westen, S. C., Nimon, J., & Zimmerman, E. (2012). Neuropsychological benefits of stationary bike exercise and a cybercycle exergame for older adults with diabetes: An exploratory analysis. *Journal of Diabetes Science and Technology*, *6*, 849–857.

Baldissera, F., & Esposti, R. (2005). Postural constraints to coupling of ipsilateral hand-foot movements. *Neuroreport*, *16*, 1615–1619.

Barella, L. A., Etnier, J. L., & Yu-Kai, C. (2010). The immediate and delayed effects of an acute bout of exercise on cognitive performance of healthy older adults. *Journal of Aging & Physical Activity*, *18*, 87–98.

Ben-Ner, A., Hamann, D. J., Koepp, G., Manohar, C. U., & Levine, J. (2014). Treadmill workstations: The effects of walking while working on physical activity and work performance. *PLoS ONE*, *9*, e88620. doi:10.1371/journal.pone.0088620

Blyth, F., March, L., Nicholas, M., & Cousins, M. (2003). Chronic pain, work performance and litigation. *Pain*, *103*, 41–47. doi:10.1016/S0304-3959(02)00380-9

Brown, W. J., Miller, Y. D., & Miller, R. (2003). Sitting time and work patterns as indicators of overweight and obesity in Australian adults. *International Journal of Obesity*, *27*, 1340–1346. doi:10.1038/sj.ijo.0802426

Buckley, J., Mellor, D., Morris, M., & Joseph, F. (2013). Standing-based office work shows encouraging signs of attenuating post-prandial glycaemic excursion. *Occupational and Environmental Medicine*, *71*, 109–111. doi:10.1136/oemed-2013-101823

Chaddock, L., Erickson, K. I., Prakash, R. S., Vanpatter, M., Voss, M. W., Pontifex, M. B., . . . Kramer, A. F. (2010). Basal ganglia volume is associated with aerobic fitness in preadolescent children. *Developmental Neuroscience*, *32*, 249–256. doi:10.1159/000316648

Cooley, P. D., & Pedersen, S. J. (2013). A pilot study of increasing nonpurposeful movement breaks at work as a means of reducing prolonged sitting. *Journal of Environmental Research and Public Health*, *2013*, 1–5. doi:10.1155/2013/128376

Davis, C. L., Tomporowski, P. D., McDowell, J. E., Austin, B. P., Miller, P. H., Yanasak, N. E., . . . Naglieri, J. A. (2011). Exercise improves executive function and achievement and alters brain activation in overweight children: A randomized, controlled trial. *Health Psychology*, *30*, 91–98. doi:10.1037/a0021766

de Frias, C. M., & Dixon, R. A. (2014). Lifestyle engagement affects cognitive status differences and trajectories on executive functions in older adults. *Archives of Clinical Neuropsychology*, *29*, 16–25. doi:10.1093/arclin/act089

Ebara, T., Kubo, T., Inoue, T., Murasaki, G.-I., Takeyama, H., Sato, T., . . . Itani, T. (2008). Effects of adjustable sit-stand VDT workstations on workers' muskuloskeletal discomfort, alertness and performance. *Industrial Health*, *46*, 497–505. doi:10.2486/indhealth.46.497

Etnier, J., Labban, J. D., Piepmeier, A., Davis, M. E., & Henning, D. A. (2014). Effects of an acute bout of exercise on memory in 6th grade children. *Paediatric Exercise Science*, *26*, 250–258.

Evers, A., Klusmann, V., Schwarzer, R., & Heuser, I. (2011). Improving cognition by adherence to physical or mental exercise: A moderated mediation analysis. *Aging & Mental Health*, *15*, 446–455. doi:10.1080/13607863.2010.543657

Fujiyama, H., Garry, M. I., Levin, O., Swinnen, S. P., & Summers, J. J. (2009). Age-related differences in inhibitory processes during interlimb coordination. *Brain Research*, *1262*, 38–47.

Fujiyama, H., Hinder, M. R., Garry, M. I., & Summers, J. J. (2013). Slow and steady is not as easy as it sounds: Interlimb coordination at slow speed is associated with elevated attentional demand especially in older adults. *Experimental Brain Research*, *227*, 289–300.

Fujiyama, H., Hinder, M. R., Schmidt, M. W., Garry, M. I., & Summers, J. J. (2012). Age-related differences in corticospinal excitability and inhibition during coordination of upper and lower limbs. *Neurobiology of Aging*, *1484*, e1–e14.

Grunseit, A. C., Chau, J. Y.-Y., van der Ploeg, H. P., & Bauman, A. (2013). "Thinking on your feet": A qualitative evaluation of sit-stand desks in an Australian workplace. *BMC Public Health*, *13*, 1–10. doi:10.1186/1471-2458-13-365

Guiney, H., & Machado, L. (2013). Benefits of regular aerobic exercise for executive functioning in healthy populations. *Psychonomic Bulletin & Review*, *20*, 73–86. doi:10.3758/s13423-012-0345-4

Hillman, C. H., Buck, S. M., Themanson, J. R., Pontifex, M. B., & Castelli, D. M. (2009). Aerobic fitness and cognitive development: Event-related brain potential and task performance indices of executive control in preadolescent children. *Developmental Psychology*, *45*, 114–129. doi:10.1037/a0014437

Hiraga, C. Y., Garry, M. I., Carson, R. G., & Summers, J. J. (2009). Dual-task interference: Attentional and neurophysiological influences. *Behavioural Brain Research*, *205*, 10–18.

Husemann, B., Von Mach, C. Y., Borsotto, D., Zepf, K. I., & Scharnbacher, J. (2009). Comparisons of musculoskeletal complaints and data entry between a sitting and a sit-stand workstation paradigm. *Human Factors*, *51*, 310–320. doi:10.1177/0018720809338173

Kamijo, K., Pontifex, M. B., O'Leary, K. C., Scudder, M. R., Wu, C.-T., Castelli, D. M., & Hillman, C. H. (2011). The effects of an afterschool physical activity program on working memory in preadolescent children. *Developmental Science*, *14*, 1046–1058. doi:10.1111/j.1467-7687.2011.01054.x

Mainsbridge, C., Cooley, P. D., Fraser, S. P., & Pedersen, S. J. (2014). The effect of an e-health intervention designed to reduce prolonged occupational sitting on mean arterial pressure. *Journal of Occupational and Environmental Medicine*, *56*, 1189–1194. doi:10.1097/JOM.0000000000000243

Mummery, W. K., Schofield, G. M., Steele, R., Eakin, E. G., & Brown, W. J. (2005). Occupational sitting time and overweight and obesity in Australian workers. *American Journal of Preventative Medicine*, *29*, 91–97. doi:10.1016/j.amepre.2005.04.003

Muzii, R. A., Warburg, C. L., & Gentile, A. M. (1984). Coordination of the upper and lower extremities. *Human Movement Science*, *3*, 337–354.

National Task Force on the Prevention and Treatment of Obesity. (2000). Overweight, obesity, and health risk. *Archives of Internal Medicine*, *160*, 898–904. doi:10.1001/archinte.160.7.898

Ohlinger, C. M., Horn, T. S., Berg, W. P., & Cox, R. H. (2011). The effect of active workstation use on measures of cognition, attention, and motor skill. *Journal of Physical Activity & Health*, *8*, 119–125.

Pronk, N. P., Katz, A. S., Lowry, M., & Payfer, J. R. (2012). Reducing occupational sitting time and improving worker health: The Take-a-Stand Project, 2011. *Preventing Chronic Disease*, *9*, 110323. doi:10.5888.pcd9.110323

Psychological Corporation. (2001). *Wechsler Test of Adult Reading*. San Antonio, TX: Harcourt Assessment.

Rasmussen, C., Holtermann, A., Mortensen, O., K., S., & Jorgensen, M. (2013). Prevention of low back pain and its consequences among nurses' aides in elderly care: A stepped-wedge multi-faceted cluster-randomized controlled trial. *BMC Public Health*, *13*, 1088. doi:10.1186/1471-2458-13-1088

Repp, B. H. (2005). Sensorimotor synchronization: A review of the tapping literature. *Psychonomic Bulletin & Review*, *12*, 969–992.

Snaith, R. P., & Zigmond, A. S. (1994). *The Hospital Anxiety and Depression Scale (HADS): Manual*. London, UK: GL Assessment Ltd.

Strauss, E., Sherman, E. M. S., & Spreen, O. (2006). *A compendium of neuropsychological tests: Administrations, norms,* *and commentary* (3rd ed.). New York, NY: Oxford University Press.

VicHealth. (2012). *Reducing prolonged sitting in the workplace: An evidence review*. Melbourne, Australia: VicHealth.

Vink, P., Konijn, I., Jongejan, B., & Berger, M. (2009). Varying the office work posture between standing, half-standing and sitting results in less discomfort. *Ergonomics and Health Aspects of Work With Computers*, *5624*, 115–120.

Wechsler, D. (1997). *Wechsler Adult Intelligence Scale–Third Edition (WAIS-III): Administration and scoring manual*. San Antonio, TX: Psychological Corporation.

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