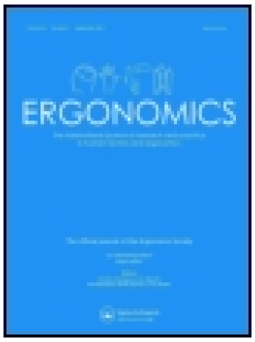

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A randomised control trial of the cognitive effects of working in a seated as opposed to a standing position in office workers

Bridget A. **RUSSELL** [a], Mathew J. **SUMMERS** [c,d *], Peter J. **TRANENT** [a], Matthew A. **PALMER** [a], P. Dean **COOLEY** [b], & Scott J. **PEDERSEN** [b],

[a] School of Medicine (Psychology), University of Tasmania, Launceston, Australia
[b] University of Tasmania Active Work Laboratory, Faculty of Education, University of Tasmania, Launceston, Australia
[c] Wicking Dementia Research & Education Centre, University of Tasmania, Hobart, Australia
[d] School of Social Sciences, University of the Sunshine Coast, Queensland, Australia

[*] Corresponding Author: Assoc Prof Mathew Summers, School of Social Sciences (ML32), University of the Sunshine Coast, Locked Bag 4, Maroochydore DC, Queensland, Australia, 4558.

ABSTRACT

Sedentary behaviour is increasing and has been identified as a potential significant health risk, particularly for desk-based employees. The development of sit-stand workstations in the workplace is one approach to reduce sedentary behaviour. However, there is uncertainty about the effects of sit-stand workstations on cognitive functioning. A sample of 36 university staff participated in a within-subjects randomised control trial examining the effect of sitting versus standing for one hour per day for five consecutive days on attention, information processing speed, short-term memory, working memory, and task efficiency. The results of the study showed no statistically significant difference in cognitive performance or work efficiency between the sitting and standing conditions, with all effect sizes being small to very small (all *ds* < 0.2). This result suggests that the use of sit-stand workstations is not associated with a reduction in cognitive performance.

KEYWORDS: sitting; standing; sedentary; cognitive function; work efficiency; randomised control trial

Practitioner summary

Although it has been reported that the use of sit-stand desks may help offset adverse health effects of prolonged sitting, there is scant evidence about changes in productivity. This randomised control study showed that there was no difference between sitting and standing for one hour on cognitive function or task efficiency in university staff.

Over the past 50 years, the workplace environment has been transformed with the advent of computer based technologies, the consequence of this being a marked increase in the number of sedentary, desk-based occupations (Hedge 2004, Owen *et al*. 2010, Owen 2012, Bennie *et al*. 2015). Currently, the average Australian office-based employee spends 75% of their workday in a seated position (Australian Bureau of Statistics 2013). Sedentary behaviour, such as prolonged sitting (more than 4 hours per day), is independently associated with a variety of chronic and potentially life-threatening health problems (Feil *et al*. 2003, Bennet *et al*. 2005, Mischel and Llewellyn-Smith 2014). Prolonged sitting is associated with an increased risk of mortality, various forms of cancer, and type II diabetes (Schofield *et al*. 2009, Matthews *et al*. 2012, Biswas *et al*. 2015). The elevated risk for these adverse health outcomes is maintained even after controlling for diet, family history and socioeconomic status.

The negative health consequences of prolonged sitting are not mitigated by short bursts of regular, moderate to vigorous intensity exercise (Pronk *et al*. 2012). Recent research indicates that exercise outside of normal work hours, even exercise that meets the recommended daily physical activity levels, does not counteract the negative physiological consequences of sitting at work for up to nine hours per day (VicHealth 2012). In an attempt to reduce the negative consequences of prolonged sitting in the workplace, a number of workplaces have commenced transforming the office environment through the use of sit-stand workstations which enable an employee to break-up prolonged time in a seated position. Research to date suggests that sit-stand workstations are an effective method to reduce the physiological consequences of prolonged sitting time (Schofield *et al*. 2009, Tissot *et al*. 2009, Pronk *et al*. 2012, Grunseit *et al*. 2013).

There is debate as to the effect that standing in the workplace may have on cognitive function. Some studies have reported better cognitive performance for standing versus sitting conditions (Nerhood and Thompson 1994, Bluedorn *et al*. 1999, Caldwell *et al*. 2003, Ebara *et al*. 2008, Grunseit *et al*. 2013, Isip 2014). For example, there is evidence that simulated workplace meetings are more efficient when performing group decision making tasks when members were standing (Bluedorn *et al*. 1999) and that employees self-report greater productivity, lower fatigue, and greater task focus when able to alternate from a standing to a seated position (Grunseit *et al*. 2013). There are several mechanisms by which standing might improve cognitive performance compared to sitting. Standing is a form of low intensity exercise. Research indicates that physically fit individuals display changes brain structure and function that are associated with superior cognitive performance (Colcombe *et al*. 2006) and that physically active children display volumetric increases in brain regions associated with specific cognitive functions (Chaddock *et al*. 2010). Nonetheless, it remains unclear whether low-intensity forms of exercise, such as standing, produce such benefits. Alternately, standing may increase physiological arousal, with this increase in physiological arousal triggering a secondary enhancement of cognitive performance. In a study of sleep-deprived participants (M = 33.7 years), standing was associated with heightened physiological arousal and improved psychomotor reaction time (Caldwell *et al*. 2003).

On the other hand, some theoretical frameworks suggest that standing might impair cognitive performance. Performance on relative complex cognitive tasks is impaired under conditions where attention is drawn away from the task at hand and directed towards the self (e.g., to monitor one's subjective experience while performing a task) (Wicklund 1975, Carver and Scheier 1981). Given that working at a standing desk involves performing a familiar task under unfamiliar conditions, standing workstations might produce an increase in self-monitoring which would, in turn, reduce performance on complex cognitive tasks. Consistent with this notion, Schraefel *et al*. (2012) found poorer performance on relatively complex cognitive tasks (e.g., involving complex attention and executive functioning) when standing rather than sitting, although the associated effect sizes were small on average (overall Cohen's d = 0.20 across several types of tasks). Additionally, Marsh and Geel (2000) found a significant slowing of verbal reaction time in a sample of 16 older women (M = 71.5 years) when standing compared to sitting. However, it is possible that this latter finding may be specific to older adults who may exhibit unique effects of postural position on cognitive performance due to age-related brain changes that independently affect cognitive performance and human locomotion (Popa-Wagner *et al*. 2012).

Apart from these conflicting results, some studies report no difference in cognitive performance between sitting and standing conditions. For example, in a study of six adults (M = 23.7 years), there was no difference in visual, verbal or auditory reaction time when standing compared to when seated (Vuillerme *et al*. 2000). Similarly, Husemann *et al*. (2009) report no dual-task cost on data entry efficiency associated with standing while working.

The inconsistent findings relating to changes in cognitive performance associated with postural position may be a result of variability in the statistical analyses and research designs utilised. For example, some studies fail to correct for family-wise error rate when performing multiple statistical comparisons across related cognitive constructs (Anderson-Hanley *et al*. 2012). Other studies examine unique participant samples such as elderly samples (Marsh and Geel 2000) or sleep-deprived subjects (Caldwell *et al*. 2003). Some fail to account for a potential novelty effect when participants work while standing for the first time (Isip 2014). It is evident that there is a need for a randomised control trial (RCT) with a larger sample size to determine if standing has an effect on cognitive performance. To our knowledge, the present study represents the first RCT investigating the effect of standing on cognitive function and overall work performance.

In the present study, we examined the effects of sitting versus standing on cognitive performance in a workplace sample. To address the problems with previous research, we recruited a representative workplace sample, used a randomized control design, and measured cognitive performance via a battery of validated, standardized cognitive tests. If improvements were observed in cognitive performance when standing, this would not only have important benefits for employees, but benefits for the organisation in terms of the potential for increased productivity. If no change in performance was observed, from an organisational perspective, the health benefits would support the transition to sit-stand workstations. Finally, if a decrement in cognitive performance was identified, this would highlight the need for an alternative intervention that produces similar positive health outcomes, without interrupting cognitive performance.

METHOD

Participants

A total of 36 employees of the University of Tasmania (26 female, 10 male) aged 22-62 years (M = 40.08, SD = 11.93) were recruited to participate in the study. All participants were employed in professional (n = 19; 52.8%) or academic (n = 17; 47.2%) roles and identified their work as predominantly desk-based sitting and had no prior exposure to sit-stand desks.

Of these, 86.1% were employed full-time and 13.9% were employed part-time. Estimated full-scale IQ scores were average or better (M = 114.19, SD = 5.26, range = 105-125).

Materials

Baseline measures

Demographic information was obtained via a short questionnaire. Baseline assessment of intellectual capacity was obtained using the *Wechsler Test of Adult Reading* (WTAR), which has established reliability and validity (The Psychological Corporation 2001). Participants were screened for clinical levels of anxiety or depression that may impair cognitive performance using the *Hospital Anxiety and Depression Scale* (HADS) (Snaith and Zigmond 1994).

Self-reported levels of workplace activity were obtained using the *Occupational Sitting and Physical Activity Questionnaire* (OSPAQ) (Chau *et al*. 2012). This was supplemented with objective assessment of workplace activity obtained with *activPAL* accelerometers to measure time spent sitting, standing and stepping. *activPAL* data were collected over an 8 hour period for each participant during a normal workday in their typical working environment.

Cognitive assessment battery

A cognitive assessment battery of six standardised tests (see Table 1) with high reliability and validity (Strauss *et al*. 2006, Lezak *et al*. 2012) was used to assess cognitive performance. Parallel versions of the cognitive tests were used where available. The Proof Reading Task was custom made and the validity of this task was assessed post hoc.

Sit-stand workstation

An electronically adjustable sit-stand workstation (ACTIU mechanical elevation sit-stand desk, model MB212), providing participants with a 0.8 m by 1.2 m workspace, was used for training and testing. The workstation height was adjusted in each condition to an ergonomically correct position for each participant (90°elbow flexion, 0° wrist extension/flexion when typing on a keyboard).

[INSERT TABLE 1 HERE]

Procedure

Each participant was assessed over two experimental blocks each lasting 5 days (Table 2) in a repeated measures, within-subjects, fully randomised controlled trial design. Participants were exposed to each experimental condition for one hour per day and were assessed in the experimental condition at day 5 of each experimental block.

[INSERT TABLE 2 HERE]

Participants completed a pre-test assessment the week prior to the first trial condition. They were verbally briefed and asked to complete the demographic survey, OSPAQ, WTAR and the cognitive assessment battery. The assessment battery test order was: HADS, DSp, TMT, LNS, DSC, Stroop, CRT and Proof Reading Test. The test order was selected to minimise potential carry-over effects between measures of related functions or modalities. Completion of the assessment battery during the pre-test ensured that potential practice effects associated with repeated testing (Strauss *et al*. 2006, Lezak *et al*. 2012) were mitigated following initial exposure to the test materials and would therefore be minimal across the two experimental conditions.

Participants were randomly assigned to one of two conditions, sitting or standing for the first week of testing. The condition order assignment was fully counterbalanced. Participants attended the laboratory, for one hour per day, for four consecutive days. The first three days comprised the training component; participants completed their normal work duties while working at the sit-stand desk in the assigned position (sit or stand). On the fourth day, participants completed the assessment battery at the sit-desk in the assigned position. In week two of testing, this procedure was repeated for the alternate condition (sit or stand). Participants attended the same time of day over the duration of the two experimental conditions, including the testing session at the end of each experimental block. Participants attended the laboratory and were assessed individually.

Statistical analysis

Data was analysed using SPSS version 22.0 for Windows. Statistical analysis was performed using the raw scores for each cognitive test and a standard criterion of $p < .05$ was applied for all analyses. MANOVA is a multivariate analysis of variance in which multiple dependent variables can be examined for differences due to an independent variable. Repeated measures MANOVA enables this analysis to occur where the dependent variables are repeated over time. Repeated Measures MANOVA can be utilised to control for family wise error rate, as multi-collinearity between dependent variables is taken into account in determining the obtained *F* value for the differences due to the independent variable (Hair *et al.* 1998). This is a common approach used in neuropsychological studies where multiple measures of related cognitive functions are used (Bondi *et al.* 2003, Saunders and Summers 2011, Clark *et al.* 2013, Klekociuk and Summers 2014).

RESULTS

Demographic Information

Data screening revealed that the sample was representative without any indicators of potential confounds. Examination of the amount of physical activity participants engaged in outside of work revealed that 52.8% of the sample self-reported the recommended 30 minutes of physical activity for at least five days per week; a figure consistent with recent Australian census data (Australian Bureau of Statistics 2012). Data collected from the OSPAQ revealed that participants report spending a median of 34.03 hours per week sitting while at work (M = 32.09, SD = 13.59, range = 4.5-57.0 hours/week), equating to a median of 6.81 hours per day seated at work (M = 6.42, SD = 2.72, range = 0.9-11.40 hours/day). Participant self-report was significantly positively correlated with the *ActivPAL* monitoring (r = .353, p = .035). Given the potential for variability in the workday, the moderate correlation suggests that the self-report was a valid measure of physical activity in the workplace. *ActivPAL* data confirms that participants spent a median of 69.15% of the work day sitting (M = 62.96%, SD = 23.66%), 23.55% standing (M = 29.03%, SD = 22.10%) and 7% walking (M = 8.01%, SD = 4.62%). Across all conditions, participants HADS anxiety and HADS depression score remained within 'normal' range (all < 7). A significant main effect of condition on anxiety

($F_{(2, 70)} = 7.92$, $p = .001$, $\eta_p^2 = .184$, power = .95) was identified, with HADS anxiety scores at pre-test being significantly higher than at either the sitting or standing experimental conditions. However, as all participant scores at each assessment remained well below clinical thresholds, this result is unlikely to be of any clinical significance. There was no main effect of condition on HADS depression score ($F_{(2, 70)} = .80$, $p = .452$, $\eta_p^2 = .022$, power = .18).

Cognitive performance

Separate repeated measures MANOVAs were conducted for measures of attention, information processing speed, short-term and working memory, and work performance. Repeated measures MANOVAs identified a significant within subjects effect on measures of attention (CRT latency, CRT errors, Stroop incongruent) ($F_{(6,30)} = 4.41$, *p*. = .003, $\eta_p^2 = .468$, power = .96); measures of information processing speed (DSC, TMT) ($F_{(4,32)} = 27.11$, *p*. < .001, $\eta_p^2 = .772$, power = 1.00); measures of short term and working memory (DSp forward, DSp backward, LNS) ($F_{(6,30)} = 4.76$, *p*. = .002, $\eta_p^2 = .488$, power = .97); but was not significant for measures of work performance (Proof Reading time, Proof Reading errors identified) ($F_{(4,32)} = .41$, *p*. = .798, $\eta_p^2 = .049$, power = .13).

Significant within subjects effects were then examined by repeated measures ANOVA (Table 3). The results of these analyses indicated clear practice effects, with poorer cognitive performance at pre-test compared to the experimental conditions (sitting and standing) across all measures of attention, information processing speed, short-term and working memory (see Table 3).

Of greatest interest were the comparisons between sitting and standing conditions. There were no significant differences between sitting and standing conditions on any of the cognitive assessment measures. As shown in Table 3, the effect sizes associated with these comparisons were all below the cut-off for a small effect ($d = 0.2$). Thus, there were no meaningful differences in cognitive performance between the sitting and standing conditions.

[INSERT TABLE 3 HERE]

DISCUSSION

The present study represents the first randomised control trial examining the effect of postural working position (sitting versus standing) on cognitive performance in adults of working age. The results of this study indicate that there is no measureable change in cognitive function when adults work at a standing desk compared to when they are in a seated position. However, we did observe a significant practice effect, evident as significantly poorer performance at pre-test assessment compared to performance at the subsequent experimental condition assessments.

The results of the present study contradict previous research reporting improved cognitive performance when standing compared to when seated (Nerhood and Thompson 1994, Bluedorn *et al*. 1999, Caldwell *et al*. 2003, Ebara *et al*. 2008, Grunseit *et al*. 2013, Isip 2014). It is evident that in several studies inappropriate or poor experimental design may have resulted in a finding of improved cognitive function when standing (Nerhood and Thompson 1994, Anderson-Hanley *et al*. 2012, Isip 2014). Experimental design factors such as the use of between-subjects design (Isip 2014), lack of control group (Nerhood and Thompson 1994) and lack of counterbalancing (Nerhood and Thompson 1994) might have introduced several potential confounding variables which were controlled for in the present study. Further, a failure to account for novelty effects (Isip 2014), the use of non-standardised sit-stand workstations (Schraefel *et al.* 2012), failure to adjust for family-wise error rate (Schraefel *et al.* 2012) or interpretation of means without referral to significance or effect size values (Nerhood and Thompson 1994, Isip 2014) are likely to have contributed to the mixed findings reported in these studies. The reliance on self-report data as a measure of work performance poses an additional problem with previous research (Brown *et al.* 2009, Tissot *et al.* 2009, Dunstan *et al.* 2013, Grunseit *et al.* 2013). Self-report data is recognised for its limitations in regards to reliability and validity (Prasad *et al.* 2004). Although employees may report feeling more alert, energised and productive (Grunseit *et al.* 2013), this self-report may be due to a variety of factors such as alleviation of the distraction of musculoskeletal pain induced by prolonged sitting, or self-justification. The results from the current study suggest that even though employees may self-report positive psychological outcomes when standing at work (Tissot *et al.* 2005, Brown *et al.* 2009, Dunstan *et al.* 2013, Grunseit *et al.* 2013), this does not necessarily translate to an objective improvement in cognitive performance.

In contrast to the results of the present study, Caldwell *et al.* (2003) reported that heightened arousal, induced by standing, triggered improved psychomotor reaction time. It is important to note that Caldwell *et al.* (2003) studied sleep-deprived subjects, suggesting that working while standing may counteract the effect of fatigue and improve reaction time. The results of the current study suggest that in a non-fatigued sample there is no change in reaction time associated with postural position while working. Thus, while standing may improve physiological arousal, this effect appears to be a restorative effect in fatigued populations.

While previous studies report improved work performance while standing (Bluedorn *et al*. 1999, Knight and Baer 2014), there is no detectable improvement in work-based performance while standing. Previous research has utilised a group task as a measure of work performance, reporting that standing, rather than sitting, decreases "*group idea territoriality"* and promotes social interaction which contributes to better group performance (Knight and Baer 2014). However, in the present study, an individual task of work performance was used in which participants were assessed on the time to complete and the number of errors identified on a proof reading task, a task congruent with the typical work roles of administrative and academic staff at a university. Ebara *et al*. (2008) utilised an individualised work performance task reporting no change in performance when standing. Collectively, these findings suggest that performance on an individualised work task does not alter when standing, whereas performance on a group based task may improve when the group is standing as opposed to sitting. In a group setting, standing may facilitate enhanced interaction and group collaboration resulting in improved productivity in the workplace.

A limitation of the current study is the short time frame for the testing period. The 10 day counterbalanced design of the current study while a clear improvement on other single session studies, did not allow for investigation of potential longer term change. It is possible that improved cognitive function may require working in a standing position over a longer period of time. This may reflect a longer term influence of improved physiological function (ie reduction in chronic health conditions associated with sedentary behaviour) resulting in a secondary improvement in cognitive function. A long-term longitudinal study is required to explore this possibility. A second limitation was the inability to implement blinding procedures to the experimental condition, a reflection of the type of intervention (sitting versus standing) that was employed. It is possible that participant's expectations may have biased their test performances in one experiment block over another. Given the design we are unable to ascertain if this effect has altered the results of this study. A final limitation of the study is the relatively brief exposure each participant had to the experimental conditions, limited to one hour duration per day. It is possible that cognitive effects may emerge with longer duration exposures over a longer period, further research is required to determine if cognitive change associated with working while standing is dose-dependent. Participants in the present study engaged in their existing work while in each experimental condition, so as to minimise any potential negative impact on each participant's daily workload. Future research could implement a non-laboratory based RCT in which there is longer daily exposure to standing and a longer duration of exposure than the 5 day duration used in the present study.

Conclusion and future directions

There is a substantial body of research highlighting the beneficial long-term effects of moderate to vigorous intensity exercise on brain structure and function (Hillman *et al*. 2004, Colcombe *et al*. 2006, Ando *et al*. 2011). The results of the present study indicate that there is no measureable change in cognitive function or work performance in a group of healthy sedentary adults. It is noted that the sample in this study were of high average intellectual capacity. This may reduce the potential of improving cognitive function in a sample with pre-existing above average cognitive ability. However, the observation that the office working sample in the present study is of above average intellectual capacity reflects the increased educational requirements on attaining office based employment in the modern Australian workplace. These findings suggest that transitioning a workforce to sit-stand workstations is unlikely to result in any short-term change in work productivity. The physiological research available suggests that transitioning the workforce to sit-stand workstations will result in a range of significant physiological health benefits, particularly in relation to chronic disease (Lehman *et al*. 2001, Brown *et al*. 2003, Pronk *et al*. 2012, Reiff *et al*. 2012). It is this longer-term improvement in improved physiological health that might have a greater benefit to cognitive function and work performance in an older workforce for whom a lifetime of sedentary workplace behaviour may have resulted in a greater level of cognitive compromise.

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Table 1: *Cognitive assessment battery*

Test	Cognitive Function
24 item Victoria version Stroop test (Stroop; Strauss *et al.* 2006)	selective attention
Four choice visual reaction time test (CRT)	sustained attention
Digit Symbol Coding subtest (DSC; Wechsler 2008)	visual grapho-motor processing speed
Trail Making Test (TMT; Strauss *et al.* 2006)	visual grapho-motor processing speed
Letter Number Sequencing subtest (LNS; Wechsler 2008)	working memory
Digit Span subtest (DSp; Wechsler 2008)	short term and working memory
Proof reading task	work performance

Table 2: *Testing Procedure*

	Week Prior	Test Week 1		Test Week 2	
	Pre-test	Day 1-3 Normal work	Day 4 Cognitive Assessment (1)	Day 1-3 Normal work	Day 4 Cognitive Assessment (2)
Condition 1 (n = 18)	Sitting →	Sitting →	Sitting →	Standing →	Standing
Condition 2 (n = 18)	Sitting →	Standing →	Standing →	Sitting →	Sitting

Table 3 – *Comparison of the effects of sitting and standing for one hour on tests of cognition*

	Pre-test *n = 36* M *(SD)*	Sitting *n = 36* M *(SD)*	Standing *n = 36* M *(SD)*	RM ANOVA *p.*	Power	Post-hoc *p.* < .05	Effect Size (sit vs stand) *d*
CRT latency (msec)	499.54 *(82.05)*	481.74 *(93.78)*	475.77 *(92.25)*	.003	.89	Pre > Sit, Stand	.06
CRT accuracy (%)	46.38 *(2.23)*	46.90 *(1.88)*	46.94 *(1.98)*	.049	.56	Pre < Stand	.03
Stroop incongruent (sec)	19.18 *(5.03)*	18.00 *(4.97)*	17.69 *(5.19)*	.018	.72	Pre > Sit, Stand	.06
DSC (total)	57.92 *(8.17)*	64.08 *(9.90)*	63.86 *(9.28)*	< .001	1.0	Pre < Sit, Stand	.02
TMT trial B (sec)	46.41 *(12.95)*	40.33 *(11.06)*	41.33 *(13.58)*	< .001	.98	Pre > Sit, Stand	.08
LNS	11.31 *(2.44)*	12.11 *(2.47)*	12.58 *(2.87)*	< .001	.97	Pre < Sit, Stand	.17
DSp (forward)	11.03 *(2.14)*	11.53 *(2.21)*	11.81 *(2.11)*	.018	.73	Pre < Stand	.13
DSp (backward)	7.03 *(2.26)*	7.72 *(2.36)*	7.97 *(2.54)*	.007	.82	Pre < Sit, Stand	.09
Proof reading task (time)	204.69 *(53.71)*	199.73 *(55.88)*	193.81 *(62.99)*	.377	.19		.09
Proof reading task (errors identified)	19.03 *(3.01)*	18.72 *(3.22)*	18.83 *(3.48)*	.855	.07		.03

Pretest = baseline testing (see Table 2); CRT = choice reaction time; DSC = Digit Symbol Coding; TMT = Trail Making Test; LNS = Letter Number Sequencing; DSp = Digit Span; post-hoc = Pairwise Least Significant Differences Test; *d* = Cohen's d