The Standing Desk Study: To what extent does working from a standing desk influence Executive Function?

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Declaration

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This Thesis/Dissertation/Research Project entitled *The Standing Desk Study: To what extent does working from a standing desk influence Executive Function?* is submitted in partial fulfilment for the requirements for the Unitec degree of Master of Osteopathy.

**Candidate’s declaration**

I confirm that:

- This Thesis/Dissertation/Research Project represents my own work;
- Research for this work has been conducted in accordance with the Unitec Research Ethics Committee Policy and Procedures, and has fulfilled any requirements set for this project by the Unitec Research Ethics Committee.

Research Ethics Committee Approval Number: 2014-1085

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Abstract

Recent evidence has highlighted the correlation between sedentary behaviour and an increased all-cause mortality. This is a problem commonly observed in the workplace due to the current ergonomic format of traditional seated workstations, where employees are spending long hours in sedentary behaviours. The introduction of standing desks into the workplace provides an alternative to reduce sedentary behaviours associated with a conventional seated workstation. As this is a workstation modification, it is necessary to determine the effects of standing on cognitive performance. Executive function is an important domain of cognition that is thought to be a key process in intelligent behaviour. Recognising the effects that standing desks have on executive function may provide support for their implementation in the workplace.

A crossover design was used to investigate the effects of a standing desk, compared with a traditional seated workstation, on executive function during a simulated working day. Thirty healthy participants (14 female, 16 male), aged between 20-49 years old, were recruited and asked to complete a number of cognitive tests over two 7.5-hour sessions, one whilst standing, and the other whilst seated. There were three testing sessions (Morning, Midday and Afternoon) throughout each day comprised of batteries of cognitive tasks, including four tasks specifically testing Executive Function: Verbal Fluency, Visuospatial Search, Stroop Effect and Trail Making.

A repeated measures ANOVA was performed to investigate whether there was a difference between the sitting and standing conditions, and Time of Day (Morning, Midday, Afternoon) was also analysed. Executive function was not found to be negatively affected by standing when compared to sitting, but evidence was found to suggest an improvement in performance in the Visuospatial Search task, the Trail Making Task, and the Stroop Effect Task across the simulated work day.

The results of this study provide supporting evidence to suggest that standing desks may be effectively implemented into the workplace without negatively influencing Executive Function. Standing desks should be considered by employers to provide
an effective workplace alternative to sitting while reducing the rapidly increasing health risk caused by sedentariness.

Key words: Standing desk, active desk, cognitive performance, cognition, executive function.
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Chapter 1: Literature Review

1.1 Introduction

1.1.2 Sedentary lifestyle

1.1.2.1 Impact on health

Sedentary behaviour is ever-present in the developing world, largely as a result of advances in technology. Pate, O’Neil, and Lobelo (2008) defined sedentary behavior as any activity that does not increase energy expenditure above the resting level; these behaviours are mostly prevalent during leisurely activities, transport, social situations, and in the workplace (Biddle, Petrolini, Pearson, 2014).

Recent evidence has suggested that the growth in sedentary behaviour has had a negative influence directly on metabolism, bone mineral content, and vascular health (Tremblay, Colley, & Saunders, 2010). Low physical activity levels and high sedentary behaviour levels have been shown to be associated with obesity (Must, Bandini, Tybor, Phillips, Naumova, & Dietz, 2007), and research has demonstrated that an increase in time spent sedentary elevates the odds of metabolic syndrome by approximately 73%, diabetes by 112%, cardiovascular disease by 147%, cardiovascular mortality by 90%, and all-cause mortality by 49% (Edwardson, Gorely, Davies, Grey, Yates, & Biddle 2012; Wilmot, Williamson, Achana, Davies, Gorely, & Grey, 2012). Hamburg McMackin, Huang, & Shenouda, (2007) demonstrated this risk by examining the effect of prolonged rest on metabolic health in adults. Participants remained in bed for at least 23.5 hours a day, and despite no changes in body weight, they experienced significant increases in total cholesterol, plasma triglycerides, glucose, and insulin resistance. This suggests that sedentary behavior may lead to an increased risk of developing metabolic syndrome. These individuals may therefore also be at an increased risk of diabetes, cardiovascular events, and mortality from resulting coronary heart disease, and cardiovascular...
disease (Edwardson et al., 2012). Interestingly, Cerin, Dunstan, Healy, Owen, & Shaw (2011) demonstrated that frequent interruptions in sedentary hours throughout the day were positively related to a decrease in metabolic risk variables, particularly with respect to weight and adipose levels, triglycerides, and plasma glucose. These findings provide a framework that suggests a reduction in sedentary lifestyle may positively impact health.

The negative implications of a sedentary lifestyle on health is a growing concern, as studies have demonstrated that large populations of adults spend approximately 55% of their waking hours in behaviors of low energy expenditure (Matthews, Chong, & Freedson, 2008). This not only negatively influences one’s physical health, but it also impacts on mental health (Sousa, Sales, Moraes, Rocha, Santos, Assis, 2014). Sedentary behaviours have a direct relationship to both cognition and mental health; research has shown that populations with predominately seated jobs, such as bankers and office workers, are three times more likely to have elevated stress levels compared to active subjects (Sousa et al., 2014). Sedentary behaviours have also been found to demonstrate a decrease in social interaction and overall physical activity, both which are strongly evident to be fundamental in protecting against mental disorders (De Wit, Straten, Lamers, & Pennix, 2011). Similarly, Vance, Wadely, Ball, & Rizzo (2005) demonstrated that depression subsequently results in a decreased level of physical activity, and this decrease in activity revealed a subsequent decline in cognitive function. Correspondingly, Comijs, Jonker, Beekman, & Deeg (2001) performed a study where depression-related sedentariness was associated with a decline in processing speed. Therefore, it is evident that sedentary behaviours may display a negative influence on cognitive function, and should thus be reduced to sustain optimal brain function.

1.1.2.2. Prevalence in workplace environments

Understanding the links of sedentary behavior and how they take place in a specific environment is important to develop effective interventions. Occupation and the
workplace have been identified as being important attributing factors to determining adult levels of sedentariness and not surprisingly, these attributing factors are only increasing due to the advances in technology. The number of screen-based desk occupations is increasing, particularly with respect to administrative, technological, and communication-based jobs (Owen, Sugiyama, Eakin, Gardiner, & Tremblay 2011). Tremblay et al. (2010), provides a brief model of generalized behavior throughout a typical day (Figure 1), and this demonstrates that sedentariness during waking hours is mostly prevalent during an average 8-hour workday whereupon people are seated at desks. This suggests that an intervention targeted at the workplace could be most effective to combat these detrimental sitting behaviours.

Given that the environment of the workplace is a key determinant of sedentary behaviour, targeting prolonged sitting time at cubicles may be the most feasible option to improve such behaviours (Owen et al, 2011). Targeting this potentially beneficial intervention is important as there is evidence to suggest that working adults with a higher occupational sitting time may not necessarily compensate for sedentariness at work by spending less time in sedentary behaviours during leisure time (Jans, Proper, & Hildebrandt, 2007). However, research has suggested that even if adults in primarily seated occupations exercise the same amount as those with a less sedentary lifestyle, they are still at a higher risk of adverse health outcomes (Banoski, 2011). It is therefore important that interventions are actively engaged in the workplace to aid in the reduction of the amount of time spent in sedentary behaviors.
1.2. Interventions for sedentary behaviours and their effects in the workplace

The World Health Organization (WHO) and World Economic Forum (WEF) jointly identify the workplace as an important setting to promote healthcare action (WHO/WEF, 2008). Many different approaches to reduce sedentary behavior in the workplace have been explored; from simple education about associated negative health implications to using active workstations. Stephens, Winkler, Trost, Dunstan, & Eakin (2014) discussed a workplace intervention with the message “Stand Up, Sit Less, Move More”, encouraging workers to take initiative for reducing their own sedentariness, alongside wearing an activity monitor to record their progress. This message delivered a reduction in workplace sitting time of approximately two hours per person in an eight-hour working day, suggesting that education may be an effective tool to help decrease sedentary behaviors.
McAlpine, Manohar, McCrady, & Levine (2007) investigated the use of a portable stepping device to increase workplace physical activity. The stepping device was found to have good acceptability within the workplace whereby the positive feedback received from its users included it was lightweight, required a low level of commitment, and was affordable. The results demonstrated that energy expenditure was increased when using the stepping device, particularly in obese participants, indicating it was a useful intervention to promote physical activity. However, the study did not demonstrate how much time was spent using the device, nor whether there was a notable reduction in sitting time. Consequently, further research is needed regarding whether utilizing stepping devices is an effective approach to reducing sedentary behavior in the workplace. Similarly, Carr, Walasaka, & Marcus (2012) evaluated the feasibility of a portable pedal exercise machine for reducing sedentary time in the workplace. The results of this study revealed that participants used the pedal machines for an average of 12 days out of 20. This showed a promising level of adherence, however unfortunately the participants only used the machines for approximately 20 minutes per day, which may not be enough time to completely reverse the adverse effects of prolonged sitting.

Treadmill desk use is another intervention that has been trialed in an attempt to reduce sedentariness at work. A one-year trial done by Koepp and colleagues (2013) found that gradually, throughout the year, daily physical activity increased, and sedentariness in the workplace decreased, by approximately 45 minutes each day. The study also applied self-rated workplace performance assessments, which demonstrated subjective findings that there were no significant changes in employee workplace performance when working from a treadmill desk. This is contrasting to Oppezzo & Schwartz (2014), who demonstrated that when analyzed under more cognitively demanding loads, whereby objective measures were recorded, treadmill desks actually decreased work performance. Therefore treadmill desks may be an effective approach to decrease sedentary behavior, but caution must be taken as they may also impede daily tasks and interrupt work performance.

Dutta, Koepp, Stovitz, & Levine (2014) employed sit-stand desks (SSD’s) with the objective of decreasing sitting time in an office setting. The use of SSD’s was primarily aimed to replace 50% of the seated working day with standing, over a
period of a month. The study demonstrated that sitting was reduced by an average of 20%, which was equivalent to eight hours in a 40-hour working week. It is important to note that this estimated time also included non-working hours, such as after work and during the weekends. The literature explained that participants were not compensating with sitting more at home from the increased standing at work, which suggests the SSD’s do not elevate fatigue levels. A notable limitation of this study is that the results demonstrate that their aim to decrease workplace sitting time were not recorded accurately, as the study did not isolate work hours alone, and included after work hours and weekends. The findings should then indicate that perhaps an 8-hour reduction is not that significant given there are 168 hours in a week, showing only a 4.7% reduction in sedentary hours. Future research is needed with respect to increasing standing time in the workplace specifically.

It is evident that an intervention to reduce sedentariness, which does not negatively influence cognition and associated work performance, is yet to be identified. As a consequence, this research project aimed to investigate five different domains of cognition: Working Memory, Attention, Perceptual Reasoning, Processing Speed, and Executive Function. The objective of this research was to investigate the effects that working from a standing desk had on executive function and how this compared to working from a seated desk. The study attempted to closely simulate a working day with cognitively demanding office-based tasks, and to compare the cognitive performance between sitting and standing. The findings helped to provide confirmation as to whether standing desks are a feasible intervention to reduce sedentary behaviour and improve productivity in the workplace. It is hypothesised that working whilst standing will demonstrate neither a reduction nor improvement in executive function when compared to seated desks. This lead to the research question: What are the effects of working from a standing desk compared with a seated desk, on cognitive performance during a simulated working day?
1.3. Active Workstations

1.3.1. Cycling workstations

As a non-weight bearing activity, cycling workstations could serve as an option for facilitating increased physical activity in desk-bound office workers (Elmer & Martin, 2014). These cycling desks are an approach to active workstations that allow the worker to remain seated throughout the day, but with an increase in energy expenditure to potentially reverse the effects of sedentary behaviour (Elmer & Martin, 2014). It is important to evaluate the practicality of a cycling workstation in an office setting, not only with respect to energy expenditure, but work performance, and cognitive performance as well.

1.3.1.1. Energy expenditure

Elmer & Martin (2014) performed a study that aimed to evaluate the amount of energy expenditure that resulted from using a cycle workstation, and how this influenced work performance. The study demonstrated that pedaling while typing on a cycling workstation elevated metabolic cost by 155 kilocalories per hour compared to typing alone. This suggests that desk-bound workers could reduce sedentariness and increase energy expenditure throughout the day without having to stand or leave their desk. Comparably, Carr, Hotaka, Luther, Rider, & Tucker (2011) also evaluated energy expenditure when using a seated active workstation during computer-based work. Energy expenditure was assessed by indirect calorimetry, along with the assessment of heart rate and muscle activity in the legs recorded by electromyography. The findings demonstrated a significant increase in energy expenditure when participants were pedaling compared to sitting. As expected, there was also an increase in lower limb muscular activation and heart rate. Unfortunately, both of the aforementioned studies failed to provide an accurate reflection of a typical working day, with Carr et al., (2011) only trialing the active workstation for 30 minutes, and Elmer & Martin (2014) only testing for 10 minutes. It is therefore difficult to say whether the results would be similar when tested on a lengthier scale where participants may have increase in their fatigue levels. A study that more accurately
reflected a typical working day would be much better suited to evaluate energy expenditure and performance and ultimately provide us with information to effectively determine the full influence cycling desks have on sedentary behaviour.

1.3.1.2. Work performance

The effects of a cycling workstation on work performance were evaluated in a study by Straker, Levine, & Campbell, (2009). The study combined keyboard and mouse performance tasks to determine if performance was obstructed when using a cycling station compared to a walking desk. The results found that the work performance showed minimal change for typing when using a cycling workstation, but a clear deterioration in mouse performance was noted; with a 5% decrease in speed, and a 61% increase in error rate. However, it is also important to note that the decline in mouse use was less than when using a walking workstation. Comparably, Elmer & Martin (2014), and Commissaris Konemann, Burford, Botter, & Douwes (2014) both noted that there was no change in typing work performance when cycling compared to when seated or when participating in other dynamic interventions. Interestingly however, some of Commissaris et al., (2014) research findings were similar to that of Straker et al., (2009), in that both studies demonstrated a decline in mouse performance at a cycling desk. Furthermore, the research demonstrated that the quality of office telephone calls were significantly lower during dynamic desk use; with cycling desks being rated the lowest quality. These findings suggest that despite minimal interruption to typing, other work tasks that need to be executed throughout the day may be hindered in performance, and therefore suggest that cycling workstations might not be feasible for the workplace. Further research for the reliability of these results for a prolonged period in the workplace is needed.

1.3.1.3. Cognitive performance

It appears that only one study has evaluated the influence of cycling desks on cognitive performance. Carr, Hotaka, Luther, Rider, & Tucker (2011) evaluated visual
learning, memory, and attention, through the use of three five-minute cognitive tests. These cognitive tests were performed once while the participant was pedalling, and once when seated, and the results demonstrated that performance in the tests was not affected when compared across the two groups. However, there was a considerable limitation of this research, in that 15 minutes of pedalling would not have provided a sufficient cognitive load to truly reflect whether cycling affected these cognitive performance variables. As can be summarised from this section, it is evident that more research is needed with respect to cognitive performance and cycling desks, and how this can be implemented in the workplace to reduce sedentariness.

1.3.2 Walking Workstations

Emerging research has demonstrated how variability in office ergonomics can encourage the reduction of sedentary behaviour in the workplace. Walking desks are an example of this, and evidence suggests that the potential health benefits of an active office desk are not only related to weight control, but also improved musculoskeletal health (Straker et al., 2009; Levine & Miller, 2007; Koepp, Manohar, & McCrady-Spitzer, 2013). This intervention is contrasting to static options such as a seated or standing desk, and thus it is important to investigate how this influences daily energy expenditure, work performance, and cognitive function.

1.3.2.1 Energy Expenditure

It is assumed that energy expenditure will increase when using a walking desk compared to when sitting down. The literature discussed will therefore aim to provide insight into how energy expenditure can be translated to benefit workers using a treadmill desk. Levine & Miller (2007) provide a good example of how using treadmill desks can benefit obese participants with weight loss. Their study found that walking while working expended approximately 100 kilocalories per hour, which was higher when compared to using a seated or standing desk. This research suggests that if obese individuals were to replace the time spent sitting with treadmill desk use by 2–
3 hours per day, they could lose up to 20-30kg in a year (Levine & Miller, 2007). Similarly, Koepp et al., (2013) demonstrated that weight loss when using the treadmill desks was highest in obese participants when compared with other workstations. However, Koepp et al., (2013) did not find the weight loss rates were as high as suggested by Levine & Miller (2007), and suggest that future studies will need to monitor food intake when using a walking workstation to maximize weight loss effects.

The notable increase in energy expenditure in both of the aforementioned studies is important, as this has an influence on metabolic activity. Dunstan, Bertovic, Cerin, Hamilton, Healy, & Kingwell (2012) examined the acute effects on postprandial glucose and insulin levels of uninterrupted sitting compared with sitting, which was interrupted by brief bouts of walking. The study demonstrated that short two-minute spells of treadmill walking in between 20-minute periods of sitting lowered postprandial glucose and insulin levels in overweight participants. This suggests that either a walking desk set-up or regular walking breaks in an office setting may improve glucose metabolism, and potentially reverse the harmful effects of sedentariness while also increasing energy expenditure. While this is a remarkable finding, it is important to discuss how this may influence work performance and cognitive load, as the increased number of disruptions may affect productivity and focus and this will no doubt be a primary consideration that employers will observe prior to initiating any such intervention.

### 1.3.2.2 Work Performance

To be a feasible option in an office setting, it is important that treadmill desks are not only used to increase energy expenditure, but that they allow the workers to correctly perform their daily work tasks. Labonte-LeMoyne, Santhanam, Leger, Courtemanche, Fredette, & Senecal (2015) evaluated a reading-recall performance task as well as a self-reported evaluation of attention to tasks when using a treadmill desk. The reading-recall task required the participants to read text and emails for a period of 40 minutes while walking, and then answer a true or false questionnaire
about the reading content. The results found that the walking group was 30% more likely to correctly answer the questions, when compared to the control-seated group. An increase in attention was also noted with participants self-reporting that they perceived their on-task attention was higher when using a treadmill desk. This research suggests that short bouts of walking in an office setting may be effective in not only maintaining working memory and attention for workplace tasks, but also possibly improving it. On the contrary, a study performed by Oppezzo & Schwartz (2014) found that while creativity was improved when using a walking workstation, working performance was diminished. There is most likely a discrepancy between these two study findings as Oppezzo & Schwartz’s (2014) study utilized a convergent thinking task that likely required a greater cognitive workload, compared to the simple text and email reading task such as what was used in Labonte-LeMoyne’s (2015) study. These results are noteworthy, as it is assumed that due to modern technological advances, most people can comfortably read and recount emails without much cognitive stress. However, when faced with tasks that may require more cognitive load, their performance was decreased. Similarly, Thompson & Levine (2011) looked at transcription rates over an eight-hour period when using a treadmill desk compared to when seated. The research demonstrated that transcription rates were approximately 20% slower when walking compared to when sitting down. This could suggest that treadmill desks may be a feasible option to use during the day for simple tasks such as emailing, reading, and brainstorming, but unsuitable for more cognitively demanding tasks.

1.3.2.3. Cognitive Performance

As the literature previously discussed suggests, work performance tasks may be hindered when using a walking desk. Yet, it is important to understand if hindrance simply involves fine motor-skill tasks such as typing and mouse clicking, or if a deeper connection to cognitive function is present. John, Bassett, Thompson, Fairbrother, & Baldwin (2009) evaluated how treadmill desks influence stimulated working tasks, with particular focus on attention, processing speed and reasoning. The study found that walking desks negatively influenced verbal and mathematical reasoning, but akin to Labonte-LeMoyne et al., (2015) reading-recall was not
affected. Ohlinger, Horn, Berg, & Cox (2011) evaluated motor speed and motor control using the ‘digital finger-tapping test’. The results demonstrated that when compared with sitting and standing, walking had the lowest scores for motor function. John et al., (2009) suggests that the results of the verbal and mathematical tasks may be present due to the increased complexity of performing multiple tasks (for example, walking and solving an equation) that require a more complex interaction than reading alone. Given the findings of the above studies, it would be easy to conclude that treadmill desks may not be appropriate for the workplace. However, it is apparent that research in this area does not provide an accurate reflection of treadmill desks on cognitive performance. It is necessary that cognitive function be better examined so that employers are educated about the possible benefits of introducing active workstations in the workplace.

1.3.3. Standing Workstations

A standing workstation aims to elevate energy expenditure above a level associated with sitting, while remaining tolerable for extended intervals and minimally cognitively disrupting from the primary task (Tudor-Locke, Schuna, Frensham, & Proenca, 2014). In contrast to active workstations, standing desks provide a static alternative to improve sedentary behaviours associated with a conventional seated workstation, whilst potentially minimally disturbing cognitive processes (Tudor-Locke et al., 2014). Woollacott & Shumway-Cook (2002) discuss that gait is not an automatic process, and it requires additional information processing. Therefore, when using an active desk such as a treadmill desk, compared to a static alternative, this additional cognitive demand may have the potential to reduce work performance. It is important to further investigate how a standing workstation will influence both energy expenditure and cognitive function.

1.3.3.1. Acceptability
Chau, Daley, Dunn, Bauman, & Srinivasan (2014) examined the feasibility and acceptability of standing desks in an office setting. The study recruited 42 participants, who used an adjustable standing desk for a period of four weeks, and then reported back about their experience. The results demonstrated that positive feedback was generally related to the ease of using the workstation, the added benefit of knowing that the change was beneficial for their health, and having choice and flexibility in selecting whether to sit or stand. The negative feedback was related to participant perceptions of the physical device, such as loss of desk space or the distance of the computer from their eyes, rather than the act of having to stand to work. Similarly, Dutta et al (2014) also found that the major issue regarding the standing desks was the loss of work-surface compared to a seated desk. However, despite the complaint, the desks had good acceptability with 26 out of the 28 participants reporting eagerness to continue using them at the end of the study, and had them permanently installed in the office. Alkhajah, Reeves, Eakin, & Winkler (2012) also found that despite reported issues with desk space for the mouse, 15 of the 18 participants surveyed said that if the option was available, they would not go back to their original set up after using a standing desk. Comparably, Grunseit, Chau, & Bauman (2013) found that out of 18 participants trialling a sit-to-stand desk, only three reported using the desk infrequently. Both the quantitative and qualitative data revealed that participants did not show a particular preference to stand or sit for specific tasks, suggesting that standing desks are suitable for a range of office workers. These studies demonstrate that standing desks are generally well received in the office setting, with the major issues being related to the desk set-up itself, rather than any discouragement arising from prolonged standing.

1.3.3.2. Energy Expenditure

As a static alternative to sitting, it is important to understand how much energy is expended when working from a standing desk, particularly as it cannot be directly compared to using a dynamic desk such as cycling or walking. Reiff (2012) looked at the difference in energy expenditure when using a standing desk compared to sitting. Two 45-minute periods of data collection were observed, with the participants demonstrating that caloric expenditure was significantly higher at approximately 0.34
kilocalories per min when using the standing desk. This suggests that participants would expend at least 115 kilocalories during an eight-hour day when working from a standing desk (Reiff, 2012). This expenditure is noteable, as it has been suggested that increasing energy outflow by 100 kilocalories per day could prevent weight gain in many populations (Hill, Wyatt, Reed, & Peters, 2003). Correspondingly, Speck & Schmitz (2011) compared energy expenditure when sitting to standing for obesity prevention. They described that there was minimal improvement in energy expenditure between the two conditions during a 7-minute interval of computer work. Despite these findings, research on the total energy expenditure of standing desks during an uninterrupted, eight-hour day is still relatively scarce. This is due to both the variability of standing hours in each trial, and due to research being focused on reduction in hours spent sitting rather than on the total energy exhausted, therefore further research is needed.

1.3.3. Health-Related Outcomes

Few studies have discussed the physiological health related outcomes of using a standing desk. As mentioned earlier, sedentariness increases the likelihood of weight gain and metabolic disease, and for this reason, it is important to understand how standing desks could slow, or better yet, reverse these negative consequences of prolonged sitting. Alkhajah et al. (2012) investigated cardiometabolic risk factors when using a standing desk compared to a sitting workspace. The study measured fasting blood lipids, glucose, total cholesterol, high-density lipoproteins [HDL], and triglycerides at baseline, one-week, and three-month intervals. They then compared the two interventions results at their respective time-points. The study found a significant increase in standing HDL cholesterol of 0.26mmol/L compared to sitting, which suggests that standing desks may help to lower the risk of heart disease by improving a risk factor that is known to be a significant contributor in cardiac disease. Cox, Guth, Kellems, Brehm, & Ohlinger (2011) demonstrated that there was no change in blood pressure when comparing working from a standing desk to sitting for a period of 20 minutes, but heart rate was elevated to approximately 90-100 beats per minute (bpm) compared with 80bpm when sitting, indicating a positive cardiovascular response. Although further research is needed, the two studies
discussed, along with the supposed increase in energy expenditure, give some promise that there may be some health-related benefits of standing compared to sitting.

1.3.3.4. Musculoskeletal discomfort

It has been documented that the incidence of musculoskeletal complaints of the neck, shoulders and lower back are associated with prolonged sedentary work due to a constrained posture (Waersted & Westgaard, 1997). Discomfort is an important factor in determining whether standing desks are feasible in the workplace, and whether standing could potentially help to alleviate some of these complaints. Dutta et al., (2014) discussed that participants reported feeling more fatigued, especially in the lower back and lower extremities during the first week of using a standing desk. After the second week, however, the pain and discomfort was no longer present, suggesting that an adjustment period may be needed for the body to get used to the change in positioning. Interestingly, Chau et al., (2014) recently investigated how the change from a constrained sitting posture to standing affected lower-back pain individuals. The study found that many participants were willing to trial a standing desk due to pain in their lower back, and self-reported outcomes stated that their back pain decreased and they felt less fatigued when using a standing desk. Similarly, Hedge (2004) reported that of 33 adults surveyed in an office setting, 27% reported an improvement in neck pain and 30% reported an improvement in upper back pain when using a standing desk. Pronk, Katz, Lowry, & Payfer (2011) also demonstrated a significant decrease in upper back and neck pain over a seven-week period when working from a standing desk Beers, Roemmich, Epstein, & Horvath (2008) compared working while sitting, standing, and using a therapy ball. The study found that fatigue levels were lowest when working whilst standing, but comfort levels were also noted to be the lowest when working whilst standing. This may be because the participants were only tested for a period of 20 minutes, compared to studies by Dutta et al., (2014); Pronk et al., (2011); & Chau et al., (2014) who tested for various weeks, again suggesting an adjustment period may be necessary.
1.3.3.5. Work Performance

As with any other workstation intervention, analysing how work performance is influenced by using a standing desk is important to determine whether or not they will be appropriate to use daily. Commissaris et al., (2014) compared a variety of interventions: sitting, standing desks, treadmill desks, cycling desks, and a semi recumbent elliptical trainer, to evaluate computer performance and cognitive function. A typing task, a reading task, a telephone task, and a task examining mouse dexterity were evaluated over all six conditions, along with four cognitive tasks examining attention, perceptual performance, executive memory, and working memory. The results found that all perceived performance tasks scored lower when using all four dynamic workstations compared to when seated, but when standing, perceived performance improved. The four cognitive tests were not affected by standing, nor was the quality of telephone calls, but deterioration was noted for mouse speed use when compared to sitting. Interestingly, a study by Hasegawa, Inoue, Tsuetsue, & Kumashiro (2001) found that alternating between sitting and standing over 90 minutes had an increased work performance when compared to just sitting. Ebara, Kubo, Murasaki, Takeyama, Suzumura, Niwa, & Tachi (2008) also found that a work performance test using transcription was highest during a period of ten minutes of standing followed by five minutes of sitting when compared to sitting in an elevated high-chair, or sitting alone. Unfortunately, neither study evaluated standing work performance alone and there is a gap in the research for evaluating prolonged standing on work and cognitive performance.

1.3.3.6. Cognitive Performance

Only one study has been known to look directly at how cognitive function is influenced when working from a standing desk. A randomized controlled crossover trial by Schraefel, Jay, & Andersen (2012) examined six individual cognitive executive function domains: executive function, complex attention, cognitive flexibility, psychomotor speed, reaction time and processing speed. Sixteen male participants performed tests related to these domains on a laptop while either sitting or standing, for approximately an hour including a rest period. The results found that
there was minimal change to most domains when standing compared to when seated, apart from complex attention, which was considerably better when participants were seated. This study stated that although other cognitive performances were uninterrupted, the ability to keep a sustained focus, to resist distraction, and to switch attention between tasks was impeded, suggesting that in a working environment participants are unlikely to work as efficiently standing as they would sitting. However, it is important to note that there are several limitations to this study that may have influenced these results. Firstly, the amount of time spent doing the cognitive testing and standing did not accurately portray a full working day. As described earlier by Dutta (2014), an adjustment period may be needed to acquaint the user with a standing desk prior to being able to observe any improvements in work performance. Therefore when taking into consideration that none of the participants had previously worked at a standing desk, the unfamiliarity of the experience is likely to have promoted possibly unfavourable results. The location of a laboratory instead of an office setting also provided a false representation of a working day. The sample size of the study was small with only 16 participants, all of whom were male. It is generally recognized that the average woman has less aerobic power and muscular strength than a man (Shephard, 2000), and this may influence the males ability to stand comfortably for prolonged periods, suggesting that the results of Schraefel’s (2012) study may be somewhat biased. Another critique to note is the amount of rest time between sitting and standing, and between cognitive tests. The study does not disclose how long the rest period was, so there is no way to know how this influenced the results. It also raises the question of how long the cognitive tests ran for during the hour of testing, as they could have been brief and not demanding enough to fully emphasize cognitive load when standing or sitting. Despite these critiques, it is an important basis which thereby enables further and more accurate research to occur.

1.4. Executive Function

1.4.1. Executive function domain

Executive function is an umbrella term that includes complex cognitive processing,
requiring the co-ordination of several sub-processes to achieve a particular goal (Elliot, 2003). Executive processes are believed to be involved with the frontal lobes of the brain, and executive control is necessary for everyday tasks seen in the workplace. These are high demand cognitive actions that involve active control over processes to work to optimize how we behave in unfamiliar circumstances (Etnier & Chang, 2009). These everyday tasks require us to formulate a goal, to plan, to choose between alternative behaviours to reach this goal, inhibit certain behaviours, and to compare plans with respect to their relative probabilities of success, and their relative efficiency of attaining the chosen goal (Rabbit, 1997). Understanding executive function is essential because it is thought to be a key process in intelligent behaviour, it varies across our life span, and it influences performance in various environments (Banich, 2009). The consequences of executive dysfunction for humans can be dramatic, as demonstrated by the large range of neurologic and neuropsychiatric disorders in which such dysfunction negatively affects outcome and quality of life (Barnes, Dean, Nadam, & O’Connell, 2011). Four primary tests have been identified to effectively measure these executive processes when working from a standing desk, and these include Trail Making, Stroop Test, Verbal Fluency, and a Visuospatial Search. These four measures were chosen as part of this study due to the known research of frontal lobe testing, or having been administrated in similar studies. Given that executive function is likely to be influenced by lifestyle variables such as nutrition, level of physical activity, occupation, and substance use, it is then important that these details are considered in such a study whereupon cognitive performance is measured as a possible limitation of a dynamic workstation.

1.4.2 Physical activity effect on executive function

The influence of physical activity on an individual’s ability to think clearly and make suitable decisions has been well documented, particularly with respect to executive function. The influence exercise has on the inhibition\textsuperscript{1} aspect of executive function has been explored in many studies also (Chang, Chi, Etnier, Chu, & Zhou, 2014; Byun, Hyodo, Suwabe, Ochi, Sakairi, & Kato, 2014; Sibley, Etnier, & Le Masurier, 2011).

\textsuperscript{1} Inhibition can be defined as the ability to stop ones own behaviour at the appropriate time, including supressing actions and thoughts.
2006). These studies all used a task known as the Stroop Effect, which first requires participants to read a card with the words of colours; secondly, a condition involving reading the colours, and lastly a condition that loads executive function whereby the participant is required to inhibit automatic reading and engage colour naming instead. Sibley et al., (2006) found an improvement in the colour-word interference condition following a short period of exercise using a treadmill. This demonstrated that executive functioning, related to goal-oriented processing, is increased with physical activity. Chang et al., (2014) also found that improvement of all three conditions of the Stroop Effect were evident after brief bouts of resistance-based exercise. Using a non-invasive functional near-infrared spectroscopy [fNIRS], Byun et al., (2014) demonstrated that an acute period of mild cycling facilitates performance in the Stroop colour-word interference condition as well. This research shows that cognitive inhibition may not only be maintained with activity, but it may also be enhanced by both aerobic and resistance-based exercise.

Hung, Tsai, & Chen (2013) investigated cognitive function when exercising with the use of “The Tower of London Task”. The task involved 10 problems that were presented to the participant, and these problems aimed to evaluate planning and goal formation. The results demonstrated that bouts of aerobic exercise significantly improved planning and goal forming performance, with the most prolonged bout of exercise (60 minutes) demonstrating the most favorable results. Gapin & Etnier (2010) used the same task to evaluate if exercise can improve cognition in children suffering from attention-deficit hyperactivity disorder. The results were akin to Hung et al., (2013), demonstrating that children had stronger levels of executive output with higher levels of physical activity. The ability to task switch or choose between alternative behaviours to reach a particular goal is one of the main aspects of executive function. Dai, Chang, Huang, & Hung (2013) and Hillman & Kramer (2006) both demonstrated that both high and low levels of exercise helped to exhibit shorter reaction times when performing a switching task, compared to participants who did not engage in any physical activity. The positive influence physical activity seems to have on cognitive function provides a background for future interventions such as the use of a standing desk.
1.4.3. Gait, Posture, and Executive Function

Several studies have examined the relationship between cognitive function, gait, and postural stability (Kearney, 2013; Reilly et al., 2008; Hawkes et al., 2012; Ijmker & Lamoth, 2012; Muir-Hunter, 2014; Burracchio et al., 2011). Postural control was originally considered to be automatic with minimal processing of information, but recent research has shown that maintaining or regaining stability requires cognitive resources (Reilly, Donkelaar, Saavedra, & Woollacott, 2008). The ability to choose between various behaviours, and its relationship with stability and gait, was examined by Hawkes, Siu, & Woollacott (2012). The research investigated why older adult’s lost stability when walking and performing a secondary task, and found that neuromuscular and executive function deficits in task switching may interact to exacerbate gait instability. Ijmker & Lamoth (2012), Burracchio, Mattek, Dodge, Hayes, & Pavel (2011), and Kearney (2013), found similar results related to executive function in gait and falls. The studies all found an association between poor executive function and declines in gait control, where impaired executive function was reported to be associated with more serious falling patterns in older patients, even if there was no previous impairment in balance. Muir-Hunter, Clark, McLean, Pedlow, & Odasso (2014) discussed the influence of executive function on postural control. Similar to the previous studies that have been discussed earlier, the results showed that poor balance was associated with poor performance on executive function cognitive testing. The research suggests that future studies should look at whether cognitive training strategies could potentially improve balance and postural control.

1.4.4. Occupational effects on executive function

Long working hours have been found to be associated with cardiovascular and immunologic responses, reduced sleep quality, and an unhealthy lifestyle, likely due to sedentary behaviors (Van der Hulst, 2003). The effects of occupation on cognitive function have been examined by two studies (Beck, Gerber, Brand, & Puhse, 2011; & Virtanen, Archana, Ferrie, Gimeno, Marmot, 2008). Virtanen et al., (2008) found
that when compared with working 40 hours per week at most, working more than 55 hours per week was associated with lower scores in the cognitive testing of vocabulary. The study also showed that working longer hours demonstrated a decline in performance on a reasoning test, suggesting that despite possible external factors, executive function may be impaired when people are in high demand occupations. High demand and high stress jobs can lead to burnout; a work related syndrome that is a known risk factor for depression. Beck et al., (2013) examined how burnout can reduce executive function processes, and how it can recover. Cognitive flexibility, or task switching, was the key element of the study, along with an aerobic exercise program. The results demonstrated that cognitive flexibility within executive function is significantly reduced when experiencing burnout syndrome, but participants were able to improve back to the levels of healthy controls with an exercise program. The studies indicate that occupation can affect how cognitive processes occur, but also that the effects can be reversed with lifestyle changes.

1.4.5. Nutritional effects on executive function

The effects of nutrition on cognition were examined by Kesse-Guyot, Andreeva, Lassale, Ferry, & Jeandel (2013). The study involved participants adhering to a Mediterranean diet to evaluate how this would influence various domains of cognitive processing, but in particular used a “Verbal Fluency” task to evaluate general-knowledge memory within executive function. The follow-up tested memory difficulties and cognitive function at a baseline after two years of a Mediterranean dietary change, and found that there was no difference to cognitive functioning in any domain. Riggs, Sakuma, Chou, & Pentz (2010) evaluated food intake in children and its relationship to cognitive function. They found that lower scores of executive functioning were associated with an increase in snack food intake, which is also a risk factor for obesity. The study hypothesized that children with enhanced executive inhibition skills are better at inhibiting the emotional characteristics of snack food, suggesting that cognitive function influences nutrition, but not interchangeably.
1.4.6. Substance use and executive function

It has long been discussed whether substance use influences cognitive performance. Loeber, Nakovics, Kniest, Kiefer, Mann, & Croissant (2012) looked at opiate-dependent patients and investigated whether there was an associated impairment in brain function. Executive function is the domain that elicits the most deficits when cognition is impaired due to substance abuse, and insufficiencies can persist even after several years of abstinence. The study used the Trail-Making Test to evaluate planning, and found that this was the test that was most affected by opiate use. Ashare (2014) described how dependency on a substance, such as nicotine, could negatively impact neurocognitive function. Nicotine withdrawal was found to be associated with poor sustained attention, working memory, and response inhibition. Similarly, Rezvani (2002) demonstrated that when rats were given a combination of ethanol and nicotine their accuracy in choosing which maze was most appropriate was impaired. This interaction provides an important consideration for nicotine and ethanol abuse and the possible impact it may have on brain processes. Moderate alcohol consumption and its connection with cognitive function have also been evaluated in two studies (Stampfer, Kang, Chen, & Cherry, 2005; & Yeung, Jiang, Cheng, Liu, & Zhang, 2011). Both studies demonstrated that although moderate alcohol consumption does not seem to impair executive processing, no improvement was noted either. It is then sufficient to accept that substance use does not seem to improve cognition, and in some cases can actually cause long-term harm to cognitive processes even for a period following when the substance is evaded.

1.5. Summary

Following consideration of the literature, it has become apparent that there is a significant shortage of studies that look at the effect of active workstations and their effect on cognitive performance. Other interventions seem to have shown an improvement in either sedentary behaviour (Hill et al., 2003; Reiff et al., 2012; Koepp et al., 2013; Speck et al., 2011; Carr et al., 2011), work performance (Commisaris et
al., 2014; Hasegawa et al., 2001; Oppezzo & Schwartz, 2014; Straker et al., 2009), or cognition (John et al., 2009; Schraefel et al., 2009; Ohlinger et al., 2011; Carr et al., 2011), but have fallen short due to external factors such as acceptability, failure to reflect a full working day, ability to perform tasks efficiently, health-related outcomes, or musculoskeletal discomfort. Further research is required to improve previous limitations in the methodology of previous studies, and to further evaluate the use of standing desks as an intervention to reduce sedentariness. The standing desk study, which you are about to be introduced to, is the first to use a simulated working day to evaluate prolonged standing compared to prolonged sitting on cognitive processes. Based on the previously reviewed literature it could be suggested that there is a basis for standing desks to be a successful intervention for use in the workplace.
Chapter 2: Methods

2.1. Design

A repeated measures cross-over randomised controlled trial was completed. Thirty healthy volunteers (14 females and 16 males) aged between 20 and 49 years old were randomised (stratified block (blocks of 2) randomisation) into two groups (sitting or standing on the first day) that were matched by strata of age (three groups: 18-24, 25-35, 36-50) and gender. Participants were required to attend two ‘study days’, which ran from 9am to approximately 4:30pm as an attempt to simulate a normal working day. A 7-day (approximately, may have varied per participant) washout period was observed before the participant completed the remaining condition.

During each study day, participants were required to do three sets of 19 cognitively demanding tasks for five different cognitive domains\(^2\), and four additional work-related tasks. Two breaks were provided in between each of the three testing sessions, one at 11am for an hour (early lunch), and another at 2pm for thirty minutes (see Table 1). Participants were able to request an additional break between tasks if needed, but this was not recorded. From the 19 cognitive tasks included (see Table 2), this thesis focuses specifically on the four that analyse executive function. Tasks within the executive function domain include Trail Making, Stroop Effect, Visuospatial Search and Verbal Fluency. The other tasks, which made-up the remainder of the study day, evaluated working memory, processing speed, attention, and perceptual reasoning. The work-related tasks were Alphabetizing, Data Entry, Proofreading, and Transcription, and were aimed at loading the participant cognitively whilst portraying tasks similar to those done during an average working day. Each of the sets contained the same tasks in the same order, but the content of each task was different. If a participant completed the tasks early, they were given

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\(^2\) The four additional cognitive domains are divisions of a larger study examining cognition and standing desks (see Appendix G).
more work performance tasks to fill the two-hour slot to help distribute the same cognitive load amongst all participants.

Table 1

*Study Day Outline*

<table>
<thead>
<tr>
<th>Time</th>
<th>Study Day Layout</th>
<th>Executive Function Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:00:00 a.m.</td>
<td>Testing Set #1</td>
<td>Task 1: Trail Making</td>
</tr>
<tr>
<td>9:30:00 a.m.</td>
<td></td>
<td>Task 6: Stroop Effect</td>
</tr>
<tr>
<td>10:00:00 a.m.</td>
<td></td>
<td>Task 10: Visuospatial Search</td>
</tr>
<tr>
<td>10:30:00 a.m.</td>
<td></td>
<td>Task 15: Verbal Fluency</td>
</tr>
<tr>
<td>11:00:00 a.m.</td>
<td></td>
<td>(Early) Lunch Break</td>
</tr>
<tr>
<td>11:30:00 a.m.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12:00:00 p.m.</td>
<td>Testing Set #2</td>
<td>Task 1: Trail Making</td>
</tr>
<tr>
<td>12:30:00 p.m.</td>
<td></td>
<td>Task 6: Stroop effect</td>
</tr>
<tr>
<td>1:00:00 p.m.</td>
<td></td>
<td>Task 10: Visuospatial Search</td>
</tr>
<tr>
<td>1:30:00 p.m.</td>
<td></td>
<td>Task 15: Verbal Fluency</td>
</tr>
<tr>
<td>2:00:00 p.m.</td>
<td></td>
<td>Afternoon Tea Break</td>
</tr>
<tr>
<td>2:30:00 p.m.</td>
<td>Testing Set #3</td>
<td>Task 1: Trail Making</td>
</tr>
<tr>
<td>3:00:00 p.m.</td>
<td></td>
<td>Task 6: Stroop Effect</td>
</tr>
<tr>
<td>3:30:00 p.m.</td>
<td></td>
<td>Task 10: Visuospatial Search</td>
</tr>
<tr>
<td>4:00:00 p.m.</td>
<td></td>
<td>Task 15: Verbal Fluency</td>
</tr>
</tbody>
</table>
Table 2

*Set and Order of Cognitive Tasks*

<table>
<thead>
<tr>
<th>Task</th>
<th>Cognitive Domain Tested</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Trail Making</td>
<td><strong>Executive Function</strong></td>
</tr>
<tr>
<td>2. Symbol Search</td>
<td>Processing Speed</td>
</tr>
<tr>
<td>3. CPT-AX</td>
<td>Attention</td>
</tr>
<tr>
<td>4. Spatial Span</td>
<td>Working memory</td>
</tr>
<tr>
<td>5. Figure weights</td>
<td>Perceptual Reasoning</td>
</tr>
<tr>
<td>6. Stroop Effect</td>
<td><strong>Executive Function</strong></td>
</tr>
<tr>
<td>7. Cancellation</td>
<td>Processing Speed</td>
</tr>
<tr>
<td>8. Figural Intersection</td>
<td>Perceptual Reasoning</td>
</tr>
<tr>
<td>9. Letter number Sequencing</td>
<td>Working memory</td>
</tr>
<tr>
<td>10. Visuospatial Search</td>
<td><strong>Executive Function</strong></td>
</tr>
<tr>
<td>11. Rapid picture naming</td>
<td>Processing speed</td>
</tr>
<tr>
<td>12. CPT-Inhibition</td>
<td>Attention</td>
</tr>
<tr>
<td>13. Arithmetic</td>
<td>Working Memory</td>
</tr>
<tr>
<td>14. Matrix Reasoning</td>
<td>Perceptual Reasoning</td>
</tr>
<tr>
<td>15. Verbal Fluency</td>
<td><strong>Executive Function</strong></td>
</tr>
<tr>
<td>16. Coding</td>
<td>Processing Speed</td>
</tr>
<tr>
<td>17. PASAT</td>
<td>Attention</td>
</tr>
<tr>
<td>18. Block Design</td>
<td>Perceptual Reasoning</td>
</tr>
<tr>
<td>W1. Alphabetizing</td>
<td>Nil – Sorting cards into alphabetical order</td>
</tr>
<tr>
<td>W2. Data Entry</td>
<td>Nil – Inputting numbers into a spreadsheet</td>
</tr>
<tr>
<td>W3. Proof Reading</td>
<td>Nil – reading a text and looking for errors</td>
</tr>
<tr>
<td>W4. Transcription</td>
<td>Nil – Typing from written work into word document</td>
</tr>
</tbody>
</table>
2.2. Participants/Screening

Participants were recruited using an online research participant recruitment site called “researchstudies.co.nz”, and via word-of-mouth. All applicants were required to register on the website. An information sheet about the study was available (see Appendix A), and applicants were required to fill out a demographic questionnaire (see Appendix B) to determine their eligibility. Applicants were excluded if they had any of the following: 1) Musculoskeletal or other pathologies preventing or influencing their ability to stand for prolonged periods of time, 2) Cognitive pathologies, or known learning disabilities, such as a chronic fatigue disorder, dyslexia, or any previous serious head injuries influencing their ability to perform cognitive tasks, 3) Current usage of any medications that may affect concentration and cognitive performance, 4) Limited fluency in written or verbal English (fluency was determined by the researcher over the phone if there were any doubts with the participants ability), 5) Clinically diagnosed colour blindness (some tasks required identification of colours as an outcome measure), 6) Currently using a standing desk. If eligible to participate, applicants signed a consent form (see Appendix C) confirming their understanding of participation and confidentiality. Upon completion of the two study days, participants received gift vouchers (MTA fuel vouchers or Westfield gift cards) to the value of $200.00 as compensation for their time.

2.3. Workplace arrangement & workstations

Data were collected individually with one participant and one research assistant on a day scheduled between the applicant and researcher. The collection took place in staff offices at the Unitec Institute of Technology. The seated desk was a standard office desk, and the standing desk was custom-built for the study to ensure participants could stand comfortably with a computer at eye level and with comfortable access to a mouse and keyboard. Tasks were completed using both the computer and participant workbooks administered by the researcher.
2.4. Procedure & Testing Days

2.4.1. Familiarisation Session

Prior to the first day of testing, participants were required to attend a short familiarisation session. The session was one to two hours long, and was structured to inform the participant of what the formal study day would involve, to gain their consent, and to answer any questions the participant may have had. A brief introduction about the study was given, and the participants then completed examples of each task to familiarise themselves with the workload. It was important that the participant and researcher met face-to-face to discuss and go through these tasks. This ensured that the participant could adequately undergo a full day of testing in the time allocated.

2.4.2. Testing Days

At the beginning of both testing days, a participant log was required to be filled out (see Appendix D) to identify any potentially confounding variables such as sleep, stress, and alcohol consumption. Participants were also required to keep a diary detailing their food and drink intake throughout the day to monitor any substance that may influence cognition, such as excess caffeine consumption (see Appendix E). Participants were asked to consume the same food and drink intake on the second day of testing. At the end of each testing set, participants had to record their perceptions of fatigue using a Visual Analogue Scale (Hawker, Mian, Kendzerska, & French, 2011), which rated their level of fatigue on a scale of 0-10; with 0 being no fatigue, and 10 being the worst fatigue/tiredness imaginable (see Appendix F). This was used to indicate and monitor their general level of energy. Participants were asked to wear comfortable shoes for both of the testing days.
2.5. Outcome Measures

Four tasks were created to measure executive function. These tasks were chosen due to the known research of frontal lobe testing, and/or having been administrated in similar studies. The four measures that were tested were Verbal Fluency, Trail Making, Stroop Test, and Visuospatial Search.

2.5.1. Verbal fluency

Verbal fluency is the ability to generate as many words as possible in a specific category within a given time limit, such as words beginning with F; vegetables. The “FAS” test for verbal fluency was developed by Louis Thurstone in 1938, and has since been adapted into related tests such as the Controlled Oral Word Association Test [COWAT] using letters and categories (Pendleton, 1982). Verbal fluency has strong test-retest reliability as a measure of executive function (Rabbit, 1997), and verbal generation has validity as an executive task as it requires processes of the frontal lobe. These processes include concentration, inhibition (not repeating words already given), and working memory to keep track of recent responses.

During the verbal fluency testing, participants were asked to name nouns beginning with a specific letter or falling within a specific category, and they had 45 seconds to do so. The assistant then wrote down the words listed by the participant on a piece of paper. The number of unique words generated within the timeframe is the measure that was used for data analysis. Potential errors include repetition of words, plural words, proper nouns, words that begin with the wrong letter or do not fit the category, and words that differ from a previous response by tense. The task was repeated three times throughout both days, each time with a matched but different category.

For this study, the letters F and S were be used because of their frequency in the
English language (Semrud-Clikeman, 2009). A pilot study was run on a further five potential categories, the categories that were included in the study were fruits, vegetables, stationery and four-legged animals. Poor performance of these tests were interpreted to reflect impaired executive function (Rabbit, 1997), and were therefore used to indicate participant fatigue in this study.

2.5.2. Trail Making

John Partington first introduced trail making in 1938 as part of neuropsychological testing for executive dysfunction (Salthouse, 2011). Participants were given a sheet of paper with eight letters (A-H) and eight numbers (1-8) each separated by individual circles. Participants are asked to draw lines connecting these items in alternating numeric and alphabetic sequence (1-A, 2-B, and so on) as quickly as possible until each letter and numeral have been matched (see Figure 2).

The test has strong inter-rater reliability, and strong construct validity as it is longer and more visually stimulating than a numbered-only trail making test (Gaudino, 1995). As this study involved two, counterbalanced days, the Trail Making Tasks that were administered on Day One were the mirror image of the Trail Making Tasks that were administered on Day Two. This was done in order to maintain the reliability of the measure. Trail making tests seem simple, but reflect a number of executive processes including attention, flexibility, the ability to execute and modify a plan of action, and the ability to maintain two trains of thought at the same time (Salthouse, 2011). The time taken to complete the test was used as the primary performance metric, and was compared between the two days. The error rate was not recorded as it was assumed that errors would naturally impact completion time.
2.5.3. The Stroop Effect

John Ridley Stroop founded the Stroop Effect in 1935 (Killian, n.d.). It is highly reliable due to its strong test-retest accuracy (Jensen, 1965) and it is a valid objective test as it provides stable measures on three simple aspects of cognitive executive functioning: inhibition of behaviours, cognitive flexibility, and maintaining two trains of thought at the same time (Killian, n.d.).

For this study, the participant was presented with three task cards (see Figure 3). For the first task, a word-naming card with the words of different colours printed in black ink was provided. The second task included a colour-naming card with ‘xxxx’ printed in red, blue and green. The third task was a colour-word card with colour words printed in conflicting colours, for example the word “green” might be printed in the colour red. Here, participants were asked to say the items on the cards out loud.
as quickly as possible as per the instructions noted under each task (see Figure 3). Task 3 was the colour-word interference condition that was used to load executive function. In this task participants were required to inhibit automatic reading and engage colour naming instead.

![Stroop Task 1](image1.png)  
![Stroop Task 2](image2.png)  
![Stroop Task 3](image3.png)

*Figure 3: Example design of the Stroop Effect (Tasks 1, 2, & 3).*

2.5.4. Visuospatial Search

Visuospatial skills primarily enable planning within the frontal lobe by estimating distance and depth. Additional executive processes such as inhibitory control contribute to the generation, initiation, and inhibition of goal-directed behaviours, which are a key aspect of visuospatial search (Woods, 2013). A study done by Hockey and Geffen (2004) found that the test-retest reliability of visuospatial search skills is largely constant between two different sessions, therefore supporting that the task is an appropriate measure for this similar two-day study.

For the Visuospatial Search Task, created by Patston & Tippett (2011), 360 designs were created of 12 geometric shapes and 6, 7 or 8 coloured dots (see Figure 4).
These were arranged evenly within an 8cm x 8cm box, and participants were required to locate the difference between two very similar visual designs placed next to each other. The participant had three minutes to identify as many different items as possible by indicating the quadrant in which this difference appeared. The number of designs correctly completed was the key measure of the Visuospatial Search Task. To ensure further reliability of the measure, different sets of designs were used over the two day period.

*Figure 4:* Example design from the Visuospatial Search Task (Correct answer = Quadrant 4)
Chapter 3: Results

Analyses were performed to investigate whether there was a difference between the sitting and standing conditions. In all cases a two-way repeated-measures ANOVA was run with Time of Day (Morning, Midday and Afternoon) and Condition (Standing/Sitting) as within-subjects factors.

3.1. Verbal Fluency

The variables tested for Verbal Fluency were Verbal Fluency Attempted and Verbal Fluency Correct. Verbal Fluency Attempted was the number of words the participant was able to list in 45 seconds, and Verbal Fluency Correct was the number of correct responses listed.

For the variable Verbal Fluency Attempted there was no main effect of Condition, $F(1,29) = 0.07, p = 0.932$, or of Time of Day, $F(2,58) = 1.15, p = 0.315$. There was no interaction between Condition and Time of Day, $F(2,58) = 1.37, p = 0.263$ (see Figure 5).

Figure 5: Mean number of items attempted for the Verbal Fluency task during Sitting and Standing conditions at three times across the day.
Similarly, for the variable Verbal Fluency Correct there was no main effect of Condition, $F(1,29) = 0.10, p = 0.755$, or of Time of Day, $F(2,58) = 0.52, p = 0.564$. Again, there was no interaction between Condition and Time of Day, $F(2,58) = 1.56, p = 0.219$ (see Figure 6).

![Figure 6: Mean number of correct items for the Verbal Fluency task during Sitting and Standing conditions at three times across the day.](image-url)
3.2. Trail Making

For the variable Trail Making Average Time(s) there was no main effect of Condition, $F(1,29) = 0.23, p = 0.639$, however there was a main effect of Time of Day, $F(2,58) = 46.05, p < 0.001$. Pairwise comparisons showed that participants performed the task significantly more slowly in the Morning ($M = 24.86, SE = 1.28$) than at Midday ($M = 21.50, SE = 1.27$), $p < 0.001$, and more slowly in the Morning than in the Afternoon ($M = 21.06, SE = 1.14$), $p < 0.001$. There was no difference, however, between Midday and Afternoon, $p > 0.999$. There was no interaction between Condition and Time of Day, $F(2,58) = 0.44, p = 0.646$ (see Figure 7).

![Figure 7: Average time to complete (s) for the Trail Making task during Sitting and Standing conditions at three times across the day.](image-url)
3.3. Visuospatial Search

For the variable Visuospatial Search Correct there was no main effect of Condition, $F(1,29) = 0.01, p = 0.945$, but, again, there was a main effect of Time of Day, $F(2,58) = 28.79, p < 0.001$. Pairwise comparisons showed that task performance improved throughout the day. Participants completed the task more quickly at Midday ($M = 27.22, SE = 1.34$) compared to the Morning ($M = 25.14, SE = 1.36$), $p = 0.003$, and more quickly in the Afternoon ($M = 29.18, SE = 1.41$) compared to both Midday, $p = 0.001$, and Morning, $p < 0.001$. There was no interaction between Condition and Time of Day, $F(2,58) = 0.35, p = 0.706$ (see Figure 8).

![Figure 8: Average number of correct items in the Visuospatial Search task during Sitting and Standing conditions at three times across the day.](image-url)
3.4. Stroop Effect

There were three subtasks in the Stroop Effect task: 1) Stroop Effect Word Naming, 2) Stroop Effect Colour Naming and 3) Stroop Effect Colour Word. Each has been analysed separately for consistency.

For the variable Stroop Effect Word Naming there was no main effect of Condition, $F(1,29) = 0.65, p = 0.428$, but there was a main effect of Time of Day, $F(2,58) = 13.99, p < 0.001$. Pairwise comparisons revealed that participants were able to complete more items at Midday ($M = 114.62, SE = 2.65$) than in the Morning ($M = 109.48, SE = 2.45$), $p < 0.001$, and were able to complete more items in the Afternoon ($M = 115.60, SE = 2.69$) than in the Morning, $p = 0.001$, but there was no difference between Midday and Afternoon, $p > 0.999$. There was no interaction between Condition and Time of Day, $F(2,58) = 0.68, p = 0.513$ (see Figure 9).

![Figure 9](image)

*Figure 9:* Mean number of items completed for the Stroop Effect Word Naming task during Sitting and Standing conditions at three times across the day.

For the variable Stroop Effect Colour Naming there was no main effect of Condition, $F(1,29) = 0.23, p = 0.634$, however, there was a main effect of Time of Day, $F(2,58) = 4.53, p = 0.015$. Pairwise comparisons showed that participants were able to complete fewer items in the Morning ($M = 87.68, SE = 2.50$) than at Midday ($M = 90.53, SE = 2.72$), $p = 0.042$, and fewer items in the Morning than in the Afternoon ($M = 90.38, SE = 2.80$), $p = 0.033$. There was no difference between Midday and
Afternoon, $p < 0.999$. There was no interaction between Condition and Time of Day, $F(2,58) = 2.35, p = 0.108$ (see Figure 10).

![Figure 10: Mean number of items completed for the Stroop Effect Colour Naming task during Sitting and Standing conditions at three times across the day.](image)

For the variable Stroop Effect Colour Word there was no main effect of Condition, $F(1,29) = 0.16, p = 0.692$, however, there was a main effect of Time of Day, $F(2,58) = 3.78, p = 0.029$. Pairwise comparisons showed that participants were able to complete fewer items in the Morning ($M = 63.43, SE = 2.50$) than at Midday ($M = 67.02, SE = 2.61$), $p = 0.091$, and in the Afternoon ($M = 67.00, SE = 2.47$), $p = 0.055$, but there was no difference between Midday and Afternoon, $p > 0.999$. There was no interaction between Condition and Time of Day, $F(2,58) = 0.30, p = 0.741$ (see Figure 11).
Figure 11: Mean number of items completed for the Stroop Effect Colour Word task during Sitting and Standing conditions at three times across the day.
Chapter 4: Discussion

The effects of working from a standing desk compared to a seated desk were examined to determine if posture has an influence on executive function. The results demonstrated that performance in executive function was not reduced when standing compared to sitting in four different tasks: Verbal Fluency, Trail Making, Visuospatial Search, and Stroop Effect. Performance in all of the tasks (except Verbal Fluency) improved throughout the day, showing a performance increase at Midday and Afternoon in comparison to the Morning. This was independent of whether the participant was sitting or standing. This suggests that participants were able to engage cognitive strategies to improve their performance as they became more experienced with the task, regardless of posture.

The Visuospatial Search Task demonstrated the most change over time, with participants showing a continued increase in performance at each stage of testing throughout the day. One possible explanation for this trend is related to the sensitivity of the task, as it was originally designed to evaluate executive function in two independent groups of musicians and non-musicians (Patston & Tippett, 2011), but the current study had one collective group spread across two conditions (sitting and standing). This may have decreased the sensitivity of the task by making it more difficult to detect any differences between the similar groups, and it may also have introduced a learning effect that took place throughout the day.

The absence of significant findings when standing compared to sitting demonstrated that standing desks are sustainable when considering the performance of daily tasks, as executive functioning was not impaired during the standing day. The participants demonstrated an improvement in task performance throughout the day, which may suggest that participants increased their level of cognitive demand in order to develop strategies to execute tasks more efficiently.
Overall, the results demonstrated evidence to suggest that standing desks are a feasible alternative to replace traditional seated workstations without altering executive function. Due to the large spectrum of daily processes that closely relate to executive function, these results also provide further insight into overall cognitive functioning, and how standing desks may influence this. It is, therefore, reasonable to suggest that standing desks appear to be an effective workplace alternative to sitting while maintaining executive function and reducing associated health risks.

The results of this study are similar to the findings of Schraefel et al (2012), in which executive function was not found to be impaired when using a standing desk. Comparably, our study improved on various methodological considerations by increasing the testing time from an hour to the longer duration of two working days as well as an almost doubled sample size, including both male and female participants. A longer testing time provided a more accurate reflection of how participants would perform in various tasks throughout an average work day, and the larger study scale provided support for the external validity of our study. Cognitive testing was also repeated three times throughout each day, providing a deeper emphasis on cognitive load, and, accordingly, a more accurate performance response as to what may be expected during a normal working day in a normal office environment. These improvements in methodology emphasise that the use of standing desks may not impair executive function. Future methodological improvements may look to extend the testing time to reflect a number of consecutive days in order to further represent an average working week.

Four additional cognitive fields were tested in this study that are not reported here: Processing Speed, Attention, Working Memory and Perceptual Reasoning. Appendix G shows the overall findings of the whole project, and demonstrates that performance on a large number of tasks improved throughout the day. These findings support the proposal that perhaps participants increased their ability to form strategies to perform tasks more efficiently. Results from the Processing Speed, Working Memory and Attention domains indicate some significant improvements in performance when standing compared to sitting, as all significant findings in the
larger project were in the direction of better performance when standing. This signifies that certain cognitively challenging tasks are, in fact, improved when working at a standing desk. Thorough evaluation of these other four cognitive domains has provided additional evidence in favour of the use of standing desks to reduce sedentariness, as there were no significant negative cognitive outcomes when standing (i.e., in no instance was performance better when sitting).

4.1. Limitations

There are various limitations of this study that need to be considered when looking at future research. The data collection period was limited to two days, which only provided a short-term investigation of standing on executive function. Similar research in future should focus on the effects of standing on a daily basis to determine if this will further influence cognition. Additionally, prospective researchers may also want to consider testing participants who are already familiar with standing desks. Research has demonstrated that participants reported feeling more fatigued during the first week of using a standing desk, but after a two-week adjustment period, the pain and discomfort was no longer present (Dutta et al., 2014). Due to the absence of participants needing to acquaint themselves with a standing desk, a truer representation of the effects on cognition may be apparent under these conditions. The tasks in this study were performed three times a day for two days, and a possible subsequent learning effect might have developed. This indicates that the cognitive tests may have been repeated too many times, with low variability in the questions asked for the repeated tasks. Future studies may look to decrease the repetition of each test to avoid participants becoming too familiar with the given tasks.

4.2. Conclusion

This study has demonstrated that working from a standing desk does not negatively influence executive function, when compared to working from a sitting desk. In contrast, variable improvements were noted throughout the day for the Visuospatial
Search, Stroop Effect, and Trail Making tasks. The physical benefits of standing desks have been well reported in the literature, but representation of the full benefits of a standing desk have often fallen short with respect to the cognitive implications of prolonged standing. These results support the use of standing desks as an intervention to reduce sedentary behaviour, with the absence of a negative influence on cognitive processes that are used in daily life. The integration of the five cognitive domains Executive Function, Perceptual Reasoning, Attention, Processing Speed, and Working Memory, has provided insight into a number of cognitive processes, and the results reflect the hypothesis that working whilst standing will not have a negative influence on cognitive function. Future studies should look to evaluate standing on a daily basis, and include an extended time frame to test participants, as this will ensure a more detailed reflection of feasibility for everyday use in the workplace.
References


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Appendix A: Participant Information Sheet

To what extent does working from a standing desk influence cognitive performance?

Synopsis of project

Recent evidence shows that a high level of sedentary behavior, such as prolonged sitting, is negatively correlated with an increased metabolic risk score, risk of cardiovascular events, and all-cause mortality.

The introduction of standing desks into the workplace offers a potential solution to the inactivity problem. Given that desks are typically workplace tools, it is logical to enquire about the effects of a standing desk on cognitive performance.

The goal of this project is to evaluate the effects of working from a standing desk compared with a seated desk on cognitive performance during a simulated working day.

What we are doing

To find out more we are asking all participants to perform 7.5 hours of tasks that emulate a typical office working day (e.g., transcription, data entry...) and various validated cognitive performance measures (e.g., solving puzzles, recalling numbers). All participants will attend two days; one day performed from a normal sitting desk, and one from a standing desk. Scheduled breaks are included, and standing desk participants are allowed to sit when they feel they need to (but are "encouraged" to stand as much as comfortable).

Participants will be asked to wear comfortable footwear, and match their dietary intake (i.e., coffee, sugars) for both days.

To participate in this study you will need to be between 18 and 50 years of age, and will need to feel confident in your ability to stand comfortably for extended periods of time. You will not be able to participate if you have 1) musculoskeletal pathologies preventing or influencing your ability to stand for prolonged periods, and 2) cognitive pathologies, such as chronic fatigue or any previous serious head injury, or be taking medications, which may affect concentration and cognitive performance.

What it will mean for you

Involvement in this study will require you to attend a familiarisation session of approximately 90 minutes at the Unitec Mount Albert campus. During this session you will get to see all the tasks that will be performed during the study, and will be given the opportunity to ask questions about the study before choosing to enroll.

If you choose to enroll, you will attend a full day (9:00 am to 4:30 pm) at the Unitec Mount Albert campus where you will be allocated to either a standing or sitting desk. You will be provided with numerous tasks to perform throughout the day, and will be guided through all tasks by a researcher. All tasks can be completed from the desk, and all tasks involve varying amount of cognitive load (i.e., they are all thinking tasks). There are three break periods throughout the day, and standing desk participants are allowed to sit when needed.

You will need to also attend a second day, approximately one week later, where you will repeat the day using a different desk (everyone will do one day from each desk). Upon completion of the second day you will be compensated with $200 for your time. You may also be sent an overview of the findings upon completion of data analysis and interpretation.

If you agree to participate, you will be asked to sign a consent form. This does not stop you from changing your mind if you wish to withdraw from the project. Your parent/guardian can also ask for you to be withdrawn.

Your name and information that may identify you will be kept completely confidential. All information collected from you will be stored on a password-protected file and only you and the researchers involved will have access to this information.

Please contact us if you need more information about the project. At any time if you have any concerns about the research project you can contact the principal investigators.
Appendix B: Eligibility Criteria Form

Part 1: Eligibility

The following questions assess your eligibility to take part in the study

Is English your first language?
- Yes
- No

If not, can you describe your proficiency in English? Include the other languages you speak and how old you were when you first became fluent in English. (Many of the tasks involved in the study require proficient fluency in English)

Have you had, or do you have, any injuries or conditions that hamper your ability to stand for prolonged periods? (On one day of the study you will be required to stand for long periods of time – 1.5 hours)
- Yes
- No

Do you have, or have you had, any of the following: (many of the tasks involved in the study require sustained concentration)  
Yes/No

| a.) Serious head injuries  
  (including concussions) |
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>b.) Other issues affecting your ability to concentrate?</td>
</tr>
<tr>
<td>c.) Medication affecting your ability to concentrate?</td>
</tr>
</tbody>
</table>

Are you clinically color-blind? (Some of the tasks involve discriminating between different colours – i.e., red, blue, green)

End of Part 1 If you answered “Yes” to any of these then we regret to say you are not eligible to participate in the study, but we thank you for your interest. Depending on your answer to the first question regarding English as a first language, we may be in touch with you to discuss possible participation.

If your answer to all of the above was “No”, please complete the following demographic question: (Refer to part B)
<table>
<thead>
<tr>
<th>Part 2: General Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. First &amp; Last Name</td>
</tr>
<tr>
<td>2. Age</td>
</tr>
<tr>
<td>3. Sex</td>
</tr>
<tr>
<td>4. Height</td>
</tr>
<tr>
<td>5. Weight</td>
</tr>
<tr>
<td>6. Ethnicity</td>
</tr>
<tr>
<td>7. Phone</td>
</tr>
<tr>
<td>8. Email Address</td>
</tr>
<tr>
<td>9. Postal Address</td>
</tr>
<tr>
<td>10. Next of kin</td>
</tr>
<tr>
<td>11. Occupancy</td>
</tr>
<tr>
<td>12. What (if any) regular physical activity do you maintain (include any sports you play)?</td>
</tr>
<tr>
<td>13. What (if any) are your other hobbies (e.g., music, computer games, puzzles, reading)?</td>
</tr>
<tr>
<td>14. How would you describe the level of physical activity at your work:</td>
</tr>
<tr>
<td>- Sedentary (brief standing and walking required)</td>
</tr>
<tr>
<td>- Light (frequent standing and walking required)</td>
</tr>
<tr>
<td>- Moderate (required to lift small loads / some bending)</td>
</tr>
<tr>
<td>- Heavy (frequent lifting required, often over 10 kgs, or lots of walking)</td>
</tr>
<tr>
<td>- Very heavy (consistent lifting, often over 20 kgs, or frequent running)</td>
</tr>
<tr>
<td>15. Do you currently use a standing desk?</td>
</tr>
<tr>
<td>16. How many hours would you spend sitting in an average day at work?</td>
</tr>
<tr>
<td>17. How many hours would you spend sitting in an average day at home?</td>
</tr>
<tr>
<td>18. If you have sustained any injuries that affect your ability to work, please detail them here</td>
</tr>
<tr>
<td>19. If you experience pain on a regular or sustained basis, please provide details here</td>
</tr>
<tr>
<td>20. What academic qualifications do you hold and/or are currently studying toward? Include school qualifications.</td>
</tr>
<tr>
<td>21. Have you participated in any cognitive testing before? If so, please provide details here.</td>
</tr>
</tbody>
</table>
Appendix C: Consent Form

Participant Consent Form

To what extent does working from a standing desk influence cognitive performance

I have had the research project explained to me and I have read and understand the information sheet given to me.

I understand that I don't have to be part of this if I don't want to and I may withdraw at any time prior to the completion of the research project.

I understand that everything I say is confidential and none of the information I give will identify me and that the only persons who will know what I have said will be the researchers and their supervisor. I also understand that all the information that I give will be stored securely on a computer at Unitec for a period of 5 years.

I understand that I can see the finished research document.

I have had time to consider everything and I give my consent to be a part of this project.

Participant Signature: .......................................................... Date: ................................

Participant Name: ........................................................................................................................................

Project Researcher: .......................................................... Date: ................................

Project Researcher Name: ..........................................................................................................................

UREC REGISTRATION NUMBER: 2014-1085

This study has been approved by the UNITEC Research Ethics Committee from 25.9.14 to 25.9.17. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the UREC Secretary (ph: 09 815-4321 ext 6162. Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.
Appendix D: Participant Log

1. What day of the week is it today? Circle one.
   Monday  Tuesday  Wednesday  Thursday  Friday  Saturday  Sunday

2. In the last 24 hours, what exercise have you engaged in? Include the exercise type and intensity.

3. Do you currently have any injuries or pain? If so, please describe.

4. Are you currently on any medication or supplements? If so, please describe?

5. Do you smoke? If so, how many cigarettes have you had in the last 24 hours
   ☐ I do not smoke
   ☐ 1-5
   ☐ 6-10
   ☐ 10+

6. How much alcohol have you consumed in the last 24 hours?
   ☐ 1-2 drinks
   ☐ 3-4 drinks
   ☐ 5-6 drinks
   ☐ 7+ drinks

7. Have you taken other substances in the last 24 hours? If so, please describe?

8. How many hours sleep have you had in the last 24 hours?

9. If you were to rate your quality of sleep in the last 24 hours, what score would you give it?
   0 1 2 3 4 5 6 7 8 9 10
10. How are you feeling today (please comment on fatigue, energy, pain, discomfort, feeling unwell or rundown, have any significant life events occurred recently)?

11. What shoes are you wearing today?  
(Please ensure that you wear the same shoes each time you engage in the study)

12. Has your morning routine changed in the last 24 hours? If so, please describe.
Appendix E: Nutrition Log

1. Please provide a list of drinks you have had today (include coffee, tea, water, juices, and any energy drinks or supplement drinks. If nil, please state)

2. Provide a detailed list of food (and quantity where possible) you have consumed today (including snacks)
   - Breakfast
     - Morning Tea
   - Lunch
     - Afternoon Tea

3. Provide a list of any supplements consumed today (Example: Multivitamin, fish oil, and protein powder. If Nil, please state)
Appendix F: Example of Fatigue Scale

Example Level of Fatigue Scale

(You will be asked to fill in this form at the end of each cognitive testing session)

Circle the level of fatigue or tiredness you are feeling right now.

Where 0 = no fatigue or tiredness at all
And 10 = the worst fatigue or tiredness imaginable

0 1 2 3 4 5 6 7 8 9 10
### Appendix G: General Results of Full Standing Desk Study

<table>
<thead>
<tr>
<th>Task</th>
<th>Variable*</th>
<th>Significance Value of Main Effect of Condition</th>
<th>Significance Value of Main Effect of Time of Day</th>
<th>Significance Value of Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Domain: Processing Speed</strong></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Cancellation</td>
<td>Number Correct</td>
<td>.375</td>
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<td>Coding</td>
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<td>.496</td>
</tr>
<tr>
<td>Rapid Picture Naming</td>
<td>Total Time to Complete (s)</td>
<td>.465</td>
<td>.055</td>
<td>.110</td>
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<tr>
<td>Symbol Search</td>
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<td>&lt;.001</td>
<td>.958</td>
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<tr>
<td></td>
<td>Number of Errors</td>
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<tr>
<td>CPT-AX</td>
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<td>&lt;.001</td>
<td>.417</td>
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<td></td>
<td>Number Correct</td>
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<td>.022</td>
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<td>&lt;.001</td>
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<td>PASAT</td>
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<td>.309</td>
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<tr>
<td><strong>Domain: Working Memory</strong></td>
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<tr>
<td>Arithmetic</td>
<td>Percentage Correct</td>
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<tr>
<td>Letter-number Sequencing</td>
<td>Percentage Correct</td>
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<td>.017</td>
<td>.591</td>
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<td>Spatial Span</td>
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<td>Visual Reproduction</td>
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<td>.625</td>
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<td><strong>Domain: Perceptual Reasoning</strong></td>
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<tr>
<td></td>
<td>Average Time to Complete</td>
<td>Number Correct</td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------</td>
<td>--------------------------</td>
<td>----------------</td>
<td>-----------------------</td>
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<tr>
<td><strong>Block Design</strong></td>
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<td>.467</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt; .001</td>
<td>.689</td>
<td>.089</td>
<td></td>
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**Domain: Executive Functioning**

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*non-parametric tests shown in italics
Full name of author: Sara Ema Milovic

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Department of: Osteopathy

Degree: M.O.S.T

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