What are the effects of Sitting versus Standing on Perceptual Reasoning Performance throughout a simulated working day?

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Declaration

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This Thesis entitled What are the effects of Sitting vs Standing on Perceptual Reasoning Performance throughout a simulated working day? 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;
- The contribution of supervisors and others to this work was consistent with the Unitec Regulations and Policies.
- 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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Abbreviations

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BMI

Body Mass Index

METs

Metabolic Equivalents

WAIS-IV

Wechsler Adult Intelligence Scale IV
Abstract

Background
Sedentary behaviour has been linked to deleterious health effects. While improved health markers after standing in comparison to sitting conditions have been reported by other studies, the current evidence regarding the effect of these conditions on cognitive performance is incomplete. No studies thus far have attempted to compare the difference between sitting and standing in regards to Perceptual Reasoning performance.

Objective
To determine the effects of sitting and standing on Perceptual Reasoning performance throughout a simulated working day.

Methods
A repeated-measures cross-over design was used, with 30 healthy participants between 18 and 50 years who were age and sex matched. Participants were assigned to either standing or sitting conditions while performing a cognitive test battery three times during a 7.5 hour testing day that included three tasks of Perceptual Reasoning (Block Design, Figure Weights and Matrix Reasoning). The two testing days were split into Morning, Midday, and Afternoon testing sessions and were counterbalanced across seated and standing conditions, separated by at least a seven day washout period.

Results
There were no significant main effects found between sitting and standing conditions in any of the Perceptual Reasoning tasks. Performance across the day, however, did improve significantly in the speed of Block Design performance and the accuracy of the Figure Weights tasks. Performance across the day for the Matrix Reasoning task, however, was variable. In addition, the participants’ perception of their own fatigue increased significantly over each session as the day proceeded.

Conclusion
This study found no difference in participants’ Perceptual Reasoning performance between sitting and standing, and mixed results in terms of performance across the day (7.5 hours of testing), although fatigue increased as the day proceeded. The results support the use of standing desks in the workplace given no detriment to performance whilst standing was found. Further research into the effects of sit-stand interventions on Perceptual Reasoning, and cognitive performance in general, over longer periods of time are recommended.
Chapter 1: Literature Review

1.1 Background and study aims

Modern humans spend an increasing amount of their waking time engaging in sedentary behaviours due to technological advancements which enable decreasing requirements for physical activity (Ng et al., 2014a; Ng & Popkin, 2012; Shrestha, Ijaz, Kukkonen-Harjula, Kumar, & Nwankwo, 2015). Unfortunately, sedentary behaviours correlate highly with deleterious health effects which has forced a global movement towards decreasing sedentary behaviour in our daily lives (World Health Organisation / World Economic Forum, 2008; World Health Organisation, 2010, 2013). Work places are considered an appropriate target due to the sedentary nature of the modern work environ (World Health Organisation / World Economic Forum, 2008; World Health Organisation, 2010, 2013). Interventions designed to reduce work place sedentary behaviour in the form of active workstations, have proven to be beneficial for health when compared to sitting by increasing energy expenditure (Carr et al., 2014; Elmer & Martin, 2014; MacEwen, MacDonald, & Burr, 2015; Tudor-Locke, Schuna, Frensham, & Proenca, 2014), reducing Body Mass Index (BMI) and fat mass (John et al., 2011; Koepp et al., 2013; Levine & Miller, 2007), reducing waist circumference (Carr, Karvinen, Peavler, Smith, & Cangelosi, 2013), improving oxidative stress levels (Takahashi, Miyashita, Park, Sakamoto, & Suzuki, 2015) and improving cardiometabolic markers (Healy, Winkler, Owen, Anuradha, & Dunstan, 2015). However, despite these promising results, the effects of active workstation interventions on cognitive and work performance are varied (Chau et al., 2016; Cho, Freivalds, Rovniak, Sung, & Hatzell, 2014; Commissaris et al., 2014; Cox et al., 2011; Drury et al., 2008; Ebara et al., 2008; Elmer & Martin, 2014; Hasegawa, Inoue, Tsutsue, & Kumashiro, 2001; Husemann, Von Mach, Borsotto, Zepf, & Scharmbacher, 2009; Straker, Levine, & Campbell, 2010) and therefore require further research.

The standing workstation has been shown to be the most feasible active workstation for reducing sedentary time (Shrestha et al., 2016) without decrement to work (MacEwen et al., 2015) and cognitive performance (Bantoft et al., 2015; Cox et al., 2011; Drury et al., 2008; Ebara et al., 2008; Hasegawa et al., 2001; Husemann et al., 2009; Ohlinger, Horn, Berg, & Cox, 2011; Parry & Straker, 2013; Russell et al., 2015). Thus far, studies have measured the difference in cognitive performance between workplace sitting and standing on the cognitive domains of Working Memory (Bantoft et al., 2015; Russell et al., 2015), Executive Function (Schraefel, Jay, & Andersen, 2012), & Processing Speed (Bantoft et al., 2015; Russell et al., 2015; Schraefel et al., 2012), and yet no studies have explored the effects on Perceptual Reasoning performance. Perceptual Reasoning tasks load heavily on abstract reasoning ability, which is an ability utilized by professions such as scientists and researchers in order to test and prove theories (Barrett, Barrett, & Williams, 2003). As the effects of standing on Perceptual Reasoning is currently unknown, research into these effects are warranted.
The following literature review will explore sedentary behaviour as a global health issue; the effects of physical activity on sedentary behaviour; the effects of active workstations on health, work and cognitive performance; and the rationale for measuring active workstation effects on Perceptual Reasoning performance. Although the literature will encompass a multitude of different fields of the study, the primary focus pertains to the influence that a standing intervention may influence Perceptual Reasoning performance.

1.2 Health effects of Sedentary Behaviour

Sedentary behaviour has been defined as an adoption of seated or reclined postures expending energy at ≤1.5 metabolic equivalents (METs) (Sedentary Behaviour Research Network, 2012; Pate, O’Neill, & Lobelo, 2008) which equates to 5.25ml O₂/kg/min. This poses serious health risks to individuals in modernised societies (World Health Organisation / World Economic Forum, 2008) as 55% - 70% of waking hours are spent in sedentary behaviours (Aresu et al., 2009; Colley et al., 2011; Matthews et al., 2008) which may include watching television, playing video games, surfing the internet or working in sedentary environs such as an office. Alarmingly, adults who sit for 10 or more hours per day have a 34% higher mortality risk than adults who spend the least amount of time engaging in sedentary behaviour while a 5% mortality increase is estimated for every hour spent in sedentary behaviours (Grunseit, Chau, van der Ploeg, & Bauman, 2013). Not surprisingly, evidence is emerging regarding the positive relationship between sedentary behaviour and the likelihood of developing Cardiovascular Disease and Type II Diabetes (Proper, Singh, van Mechelen, & Chinapaw, 2011; Wilmot et al., 2012). There is also strong evidence of a relationship between sedentary behaviour and all-cause Cardiovascular Disease mortality (Proper et al., 2011), but the relationship between sedentary behaviour and Metabolic Syndrome, cardiometabolic biomarkers, obesity, and increased waist circumference is still being developed (de Rezende, Rey-López, Matsudo, & do Carmo Luiz, 2014). While a systematic review by Proper et al. (2011) found no relationship between sedentary behaviour and cancer, a recent meta-analysis by Cong et al. (2014) reported that sedentary behaviour was significantly associated with colon cancer (relative risk : 1.30, 95% confidence interval (CI): 1.22 – 1.39) and a non-significant association with an increased risk of rectal cancer. The different findings may be due to differences in search terms as Proper et al.’s (2011) focus on general health outcomes while Cong et al.’s (2014) focus was on cancer. Furthermore, Proper et al.’s (2011) review is dated and included longitudinal studies meaning an increased association between sedentary behaviour and cancer is likely.

Contrary to popular belief, recent studies have highlighted sedentary behaviour as an independent health risk factor regardless of physical activity participation (Cong et al., 2014; Helmerhorst, Wijndaele, Brage, Wareham, & Ekelund, 2009; Same et al., 2016). This means that there is no intensity of exercise that may counteract the negative effects of prolonged sedentary behaviour, despite improved health from exercise such as normalisation of blood glucose levels and insulin action, lower systolic pressure, and reduced risk of all-cause and cardiovascular mortality (Garber et al., 2011; World Health Organisation, 2010). These findings strengthen the need for
interventions to curb sedentary behaviour especially in populations with greater barriers to exercise such as in obese individuals.

Obesity is a well-known consequence of sedentary behaviour and it is considered a pathological condition arising from the chronic imbalance in the rate of change of energy stores when energy intake exceeds energy expenditure creating a positive energy balance (John, 2009).

According to a systematic analysis by Ng et al. (2014), global obesity rates are increasing at a rate requiring urgent global action. In 1980, the worldwide prevalence of obesity in men and women was recorded at 28.8% (95% UI 28.4 – 29.3); & 29.8% (29.3 – 30.2) and increased in 2013 to 36.9% (36.3 – 37.4); & 38.0% (37.5 – 38.5) respectively (Ng et al., 2014). The rapidly increasing global obesity levels appear to rise concurrently with levels of sedentary behaviour and other non-communicable diseases indicating that interventions are urgently required to reduce sedentary behaviour to help curb the obesity epidemic and other non-communicable diseases.

1.3 Sedentary behaviour prevalence

The time spent in sedentary behaviours has increased dramatically over the last 50 years. While Ng & Popkin (2012) postulate that human movement has been declining since Palaeolithic time, although the most radical changes have occurred more recently. Occupational physical activity in high income countries has decreased from 150 METs per week, in 1965, to 75 METs per week in 2014 (Shrestha et al., 2015). Since 1965 there have been many technological advancements that have supported sedentary behaviour in both our leisure and work time (Brownson, Boehmer, & Luke, 2005; Ng & Popkin, 2012) such as the introduction and ever increasing prevalence of personal computers, telecommunication and the internet. In China, between the years 1991 and 2009, occupational physical activity had reduced by 46.9% while in the US, between 1965 and 2009, occupational physical activity had reduced by 41.3% (Ng & Popkin, 2012). Additionally, Western populations currently spend an average of between 55% - 70% of their waking hours in sedentary behaviours (Aresu et al., 2009; Colley et al., 2011; Matthews et al., 2008) this may include watching television, playing video games, or surfing the internet.

In the developed world, sedentary behaviours are adopted at a young age. From as young as 3 months old many of us begin participation in sedentary behaviour which is then encouraged by seated desk postures at school, university, and for the majority of people, the work place. A telephone survey of parents (N=1009) of children 2 – 24 months old found that 40% of 3-month old children regularly watched television which increased to 90% among 24-month old children with average durations ranging from 1 hour to over 1.5 hours per day respectively (Zimmerman, Christakis, & Meltzoff, 2007). People between 12 – 21 years of age have also demonstrated a decline in regular vigorous activity (Brodersen, Steptoe, Boniface, Wardle, & Hillsdon, 2007; Caspersen, Pereira, & Curran, 2000) due to increased online activity in the forms of social networking and entertainment sites coupled with the societal shift towards increasing online availability. Greater increases in sedentary behaviour are reported in children from lower socioeconomic environs due to unsafe neighbourhoods which discourage children from outdoor play (Lowry et al., 2013). This likely
encourages habitual sedentary behaviour in this demographic and presents a fundamental societal
issue due to increasing polarization between socioeconomic groups and the high cost of non-
communicable diseases on society.

As sedentary behaviours are being established at very early stages of life, there is no surprise
that these behaviours are not improving as people enter the workforce. As would be expected, office
workers tend to sustain more prolonged sedentary behaviours throughout the working day than
manual labourers (Miller & Brown, 2004) and interestingly, the office workers are also reported to sit
for longer periods outside of work (Clemes, Patel, Mahon, & Griffiths, 2014). Sitting while performing
work tasks involves an energy expenditure of ≤ 1.5 METs per hour (Shrestha et al., 2015) and the
self-reported time spent in sedentary behaviour amongst office workers ranges from 3 to 7 hours per
working day (Brown, Miller, & Miller, 2003; Jans, Proper, & Hildebrandt, 2007; Mummery, Schofield,
Steele, Eakin, & Brown, 2005) indicating large periods of inactivity at work. These findings must
however be taken with caution considering there is likely a large degree of variability, given the
inherent subjective errors in self-reporting and the inclination to report in the more favourable
direction. Given this it is likely that sedentary behaviour was under reported which means that the
amount of time spent in sedentary behaviour is greater than reported. In order to determine where
interventions may be most called for, Parry & Straker (2013) and Thorp et al. (2012) used
accelerometers to objectively measured the amount of time office workers ((\(N = 50\)) and \((N = 193)\)
respectively) spent in sedentary behaviours at work in comparison to home. They found that
participants spent more time in sedentary behaviour at work compared to at home ((81.8\% vs 68.9\%
(\(p < 0.001)) \& (77.0\%, 95\% CI: 76.3, 77.6) respectively) and this in itself provides evidence for the
importance of establishing interventions in the workplace.

These examples present a common theme of why the workplace is an appropriate target for
interventions designed to reduce sedentary behaviours globally. Further investigation is needed to
determine the most appropriate intervention for reducing sedentary behaviours in the workplace.

1.4 Interventions to reduce sedentary behaviour

The World Health Organisation Global action plan targets a 10\% global reduction in the
prevalence of insufficient physical activity by the year 2025 (World Health Organisation, 2013). In
order to achieve sufficient physical activity levels to improve health, the American College of Sports
Medicine (Garber et al., 2011) and the World Health Organisation (2010) currently recommends an
exercise prescription for adults 18 – 64 years of age consisting of either a minimum of 150 minutes of
moderate-intensity aerobic physical activity throughout the week or a minimum of 75 minutes of
vigorous-intensity aerobic physical activity throughout the week, or an equivalent combination of
moderate- and vigorous-intensity activity which should include aerobic activity performed in bouts of
at least 10 minutes duration and activities that strengthen major muscle groups two or more days a
week (Garber et al., 2011; World Health Organisation, 2010). The World Health Organisation (2013)
plans to reduce physical inactivity by: (a) adopting and implementing national guidelines on physical
activity; (b) working with governments in actively implementing actions to increase physical activity for
all ages; (c) developing policies with relevant sectors in promoting physical activities through activities of daily life and active transport; (d) conducting public campaigns to mass media and other social networks to promote benefits of increasing physical activity to all age groups; and (e) encouraging evaluation of actions aimed at increasing physical activity to contribute to evidence-based and cost-effective actions. While these plans may be somewhat beneficial, encouraging people to undertake regular physical activity in an attempt to reduce sedentary behaviour is a complex task and 50% of people who start exercising will drop out within 3 months (Nam, Dobrosielski, & Stewart, 2012). Furthermore, given that recent evidence has shown that increasing physical activity may not be the most suitable way to reduce the health risks associated with sedentary behaviours (Cong et al., 2014; Helmerhorst et al., 2009; Same et al., 2016) interventions which decrease sedentary behaviour are needed. By altering aspects of the work environment which encourage sedentary behaviour, such as seated workstations, people may be more inclined to use these interventions.

The intensity of physical activity required to off-set sedentary behaviour may merely need to be light. Recent studies have found that light intensity exercise (1.6 – 2.9 METs), consisting of activities such as leisurely walking and light house work can reduce some of the associated effects of sedentary behaviour, such as reduced Body Mass Index (BMI), when substituted for sedentary time (Bann et al., 2015; Healy et al., 2007, 2008). This suggests that light intensity workplace interventions may be effective at reducing sedentary behaviour. While longitudinal studies have not yet been investigated, the preliminary results are promising.

These studies present strategies for decreasing sedentary behaviour and show that even though current physical activity recommendations may not be achieved by everyone positive health effects, such as reducing markers of obesity, can be observed with small behavioural changes.

1.5 Small change approaches to decrease sedentary behaviour

Small changes in energy intake and physical activity can help reduce obesity prevalence according to Hill (2009). It has been shown that an energy imbalance whereby energy expenditure exceeds energy intake by a small degree (100 kcal/day) encourages weight loss. These small changes are considered to have better prognosis of curbing obesity prevalence with long-term results compared to short-term results due to large changes made to diet and physical activity. Traditional interventions which target behavioural change to address weight loss, trend toward weight regain regardless of the length of program or follow up (Lutes et al., 2012), however smaller changes, such as participant-directed alterations to nutritional intake and physical activity (Lutes et al., 2012), are projected to be more realistic, feasible, and maintainable (Hill, 2009; Hills, Byrne, Lindstrom, & Hill, 2013). Das et al. (2009) measured the effects between small and medium changes to energy restriction in two groups, a low energy restriction group (n = 12) and a medium energy restriction group (n = 34). The low energy restriction group (10% energy restriction) produced similar changes in body weight and reported satiety compared with the medium energy restriction group (30% energy restriction) over a 12 month duration (Das et al., 2009). Between the two groups, the low energy restriction group managed to restrict their energy intake more successfully than the medium energy restriction.
restriction group supporting the effectiveness of a small change long-term approach to obesity reduction. The authors report that the low energy restriction sample size was small due to the study being a pilot study for a larger study. While the low energy restriction sample size may be too small to be able to provide a true representation of the effect of low energy restriction intervention, the finding does warrant further research with equal sized large samples in order to determine the accuracy of this finding.

Small change approaches have been found to improve biological markers indicative of non-communicable preventable diseases (Bravata et al., 2007; Lewington, Clarke, Qizilbash, Peto, & Collins, 2002). A systematic review by Bravata et al. (2007) investigated the effectiveness of pedometer use on increased step count. Out of the 26 studies reviewed, participants \( N=2767 \) who used a pedometer and walked for an additional 1 mile per day for a duration of 18 weeks achieved a 0.38 reduction in BMI (95% CI, 0.05 - 0.72; \( p = .03 \)). Intervention participants also significantly decreased their systolic blood pressure by 3.8 mm Hg (95% CI, 1.7 - 5.9 mm Hg, \( p < .001 \)). A reduction of usual systolic blood pressure by as little as 2 mm Hg would decrease stroke mortality by 10% and Ischemic Heart Disease and other vascular disease mortality by 7% according to a meta-analysis by Lewington, Clarke, Qizilbash, Peto, & Collins (2002). This finding demonstrates how small changes may effectively decrease markers of non-communicable diseases and possibly reduce sedentary behaviour.

Dolan et al. (2006) reviewed eight studies which observed changes in pedestrian activity from motivational signs encouraging pedestrians to use stairs instead of escalators to inform small step number 67 of the United States of America’s national government ‘Small Steps’ campaign. These were measured by the change in percentage of stair users during the intervention phases in comparison to a baseline phase. 45,000 observations were recorded over an average intervention period of 15 weeks in which stair use increased 2.8% ± 2.4% (\( p < .001 \)). The authors projected that a 2.8% increase in physical activity would result in weight loss of approximately 300g/person/year for those who started to use the stairs. While the effect of this intervention is small, the amount of new stair users toward the end of these interventions, with longer intervention durations displaying larger effects, may be considered an encouraging sign of delayed intervention effectiveness. While it is unknown whether foot traffic may have increased due to events which may have occurred during these studies, the amount of studies included decreases the likelihood of this occurrence. When considering how positive motivation influences performance, the usefulness of motivational posters combined with the low cost of intervention creation and maintenance displays one of the ways in which a small change in physical activity can be effectively implemented in society.

Small change interventions utilising pedometers are shown to reduce sedentary behaviour according to a meta-analysis by Qiu et al. (2015) which is an important finding as the focus was on reducing sedentary behaviour compared to increasing physical activity. As most sedentary time is accumulated at the destination such as work or home which are considered target areas of
intervention by the World Health Organisation and World Economic Forum (2008), a gap in research exists requiring research investigating small change interventions in the home or workplace.

The examples above show how small change interventions can be effective at increasing physical activity, decreasing energy intake and reducing sedentary behaviour, however the effectiveness of small change interventions in the workplace require further investigation.

1.6 Interventions to reduce Sedentary Behaviour in the workplace

As has previously been discussed, The World Health Organisation and World Economic Forum (World Health Organisation / World Economic Forum, 2008) realise the workplace as an appropriate setting for health promotion and its consequent effect on the prevention of disease. They have identified diet and physical activity as target areas in which to improve employee health. Improving such areas has the potential to increase staff morale and productivity while reducing staff turnover, absenteeism and sick leave while long-term advantages may include reduced health plan costs, workers compensation and disability costs according to a meta-analysis on economic return in workplace health promotion by Chapman (2012). Health promotion is particularly advantageous in the work setting due to the large amount of time spent at work. Furthermore, it is a good way to take advantage of the worker’s perceived social pressure to conform in work-related promotions (WHO & WEF, 2008).

The use of active transport has been proposed as an intervention to reduce sedentary behaviour (Parry, Straker, Gilson, & Smith, 2013). Yet, this may not suit everyone especially those who travel long distances to work (Torbeyns, Bailey, Bos, & Meeusen, 2014) partly due to decentralization of facilities in modern cities made accessible by car use. Fear-based avoidance of perceived and actual harmful factors relating to active transport is also considered to detract from active transport acceptance (Cheyne, Imran, Scott, & Tien, 2015; Loukaitou-Sideris, 2006). Loukaitou-Sideris (2006) reports the main concerns for active travel include crime, unattended dogs, reckless drivers, and poor infrastructure. A recent review of literature by Cheyne, Imran, Scott, & Tien (2015) identifies further barriers to active travel as the perceived exertion and discomfort of active travel compared to vehicular transport and the large distances between destinations, time constraints, carrying capacity and the increased difficulty in trip-chaining activities. Safety is also a barrier whereby the speed and proximity of automotive transport and lack of infrastructure to promote feeling of safety affect active travel uptake. There is also a barrier due to the perception of increased social status of motorists compared to pedestrians and cyclists. Furthermore, elemental effects such as weather and terrain reportedly detract from the appeal of active travel.

While active transport may be a positive way to partially reduce sedentary behaviour, the large list of barriers combined with the duration spent travelling compared to working indicate that active travel may not be the most cost effective strategy for decreasing sedentary behaviour. Interventions which target environments in which we adopt sedentary behaviour for the longest...
durations of each day, such as at home or in the workplace, would be more effective intervention choices. Most workers are provided with a workstation by their employer and are therefore encouraged physically to adopt certain behaviours, whether it is sedentary or active. In order to shift from sedentary to active behaviours a behavioural change needs to occur. A systematic review by Fjeldsoe, Neuhaus, Winkler, & Eakin (2011) reported that maintenance of behaviour change after physical activity interventions displayed increased adherence in studies which conducted prolonged exposure to an intervention (> 24 weeks) and were combined with face-to-face meetings.

Interventions which utilize computer prompts to reduce sedentary behaviour in the workplace appear to be more effective than no or minimal intervention (Cooley, Pedersen, & Mainsbridge, 2014; Evans et al., 2012). Furthermore, positive influences of increased social behaviour in the workplace, increased health status, and changed perceptions of what is viewed as healthy exercise have been reported by participants but unfortunately negatively affect work flow (Cooley et al., 2014). Evans et al. (2012) provided education about importance of reduced sitting and utilised computer prompts which encouraged standing to break up sedentary time. In comparison, the control group received education without computer prompts and found that the intervention group reduced workday sitting duration by 18 minutes (95% CI -53 to 17). Evans et al. (2012) study was limited by a small duration (5 days) and therefore long term effects are unknown.

Carter et al. (2015) studied the acute effects of different exercise interventions to break-up sedentary time at the workstation within the office environment. They projected the effect of calisthenics administered for 2 minutes per hour throughout an 8 hour working day was an energy expenditure of 128 kcal. This is considered to be 28 kcal / day more than the required 100 kcal / day to prevent or reduce weight gain (Hill, 2009). While theoretically, Calisthenics would be a positive workplace intervention, the feasibility of consciously performing 64 repetitions of these exercises throughout the day may pose a health risk for obese individuals. This study contained limitations to its design and methodological control such as interventions being performed in sequence and yet no counterbalance was utilized to determine order effects and the effects of each intervention on productivity was not measured which is an important consideration in workplace interventions. Studies which have measured the effects of breaks on productivity show increased productivity (Balci & Aghazadeh, 2003; Fritz, Ellis, Demsky, Lin, & Guros, 2013) and reduced musculoskeletal pain when breaks are introduced (Balci & Aghazadeh, 2003; van den Heuvel, de Loose, Hildebrandt, & Thé, 2003), however the enforcement and frequency of pauses in work flow which computer prompts impose, may affect productivity and job satisfaction from decreased autonomy.

Carter et al. (2015) also found that subjects who stood for 2 minutes out of 45 minutes expended 3 kcals of energy which is likely due to the effect from transitioning from sitting to standing in comparison to static standing. However, according to Júdice, Hamilton, Sardinha, Zderic, & Silva (2015) there is an increased metabolic energy cost of 0.07 Kcals / min-1 in motionless standing.
compared to motionless sitting while sit to stand transitions were measured at 0.32 Kcals / min-1
more than standing. Júdice et al.'s (2015) results are limited as motionless standing lacks real world
applicability as movement in the form of fidgeting, weight shifting or movement while standing are
normal and have been previously reported by Levine, Schleusner, & Jensen (2000) to increase
energy expenditure in a standing condition. Furthermore, the conditions in Júdice et al.'s (2015) study
were measured for a duration of 10 minutes on one occasion failing to show how reproducible the
effect was. While a comparison of metabolic energy cost between sitting, standing, and sit to stand
transitions would help guide effective interventions for reducing sedentary behaviour, the results need
to be applicable to real world settings.

In summary, while the workplace is a necessary target for reduction of sedentary behaviour,
interventions such as active travel to and from the work place and computer prompts while at the work
place appear to have too many barriers or negatively affect productivity respectively. As most
sedentary behaviour occurs at the workstation, interventions which decrease sitting at the workstation
may provide the most effective way of reducing workplace sedentary behaviour and require in-depth
investigation.

1.7 Active workstations
As sedentary behaviour, such as the seated posture, has been typified in the office setting,
interventions have been proposed to help curb this trend (Alkhajah et al., 2012; Ben-Ner, Hamann,
Koepp, Manohar, & Levine, 2014; Edelson & Danoffz, 1989; John, Lyden, & Bassett, 2015; John et
al., 2011; John, Bassett, Thompson, Fairbrother, & Baldwin, 2009; Koepp et al., 2013; Robertson,
Ciriello, & Garabet, 2013; Straker, Levine, & Campbell, 2010). Along with the aforementioned
attempts at reducing sedentary behaviour, active workstations such as sit-stand workstations,
treadmill workstations and cycle workstations have also been introduced to some working
environments. In some cases these have provided promising results regarding fat mass reduction
(John, 2009; Koepp et al., 2013; Levine & Miller, 2007) and improved work performance (Ebara et al.,
2008). However, while information on active workstation engagement has provided individuals with
some positive health benefits, negative effects to work and cognitive performance have been reported
in some of these workstations.

According to a meta-analysis by Neuhaus et al. (2014), when data from active workstation
research is pooled, a reduction of sedentary time by approximately 77 minutes over an 8-hour
workday was found. However, it was also reported that the reduction in sedentary behaviour from
treadmill and cycling interventions was correlated with a decrease in work performance. This
decreased work performance may have been due to insufficient familiarity time using the work station,
which has been reported by Ben-Ner et al.(2014).

While active workstations appear to be an appropriate intervention to reduce sedentary
behaviour, investigation into the positive and negative attributes of each are necessary to determine
the most appropriate intervention for reducing sedentary behaviour in the work place.
1.8 Treadmill Workstations

The treadmill workstation utilizes a treadmill base with a raised desk to enable individuals the ability to walk while working. The treadmill workstation concept was conceived by Edelson & Danoffz in 1989 and built by Edelson in 1993. This workstation was designed to reduce musculoskeletal dysfunction, psychological disturbance, and internal disease by decreasing the effects of seated posture on postural fixity and reduced systemic blood flow (Edelson & Danoffz, 1989). Edelson & Danoffz (1989) then compared the effects of treadmill workstations and seated workstations with 5 participants measuring word processing performance, stress and arousal indices, and the amount of body complaints. Treadmill desk performance displayed no detriment in word processing scores, a moderate reduction in bodily complaints, a slight increase in arousal indices, and a significant decrease in stress. The positive outcomes highlighted in this study provide sound reason for further research to be conducted before treadmill desks can be recommended in the work place.

1.8.1 Work Performance

Treadmill desks had initially been considered to have a negative effect on work performance (Edelson & Danoffz, 1989; John et al., 2009; Straker et al., 2010). John, Bassett, Thompson, Fairbrother, & Baldwin (2009) compared differences between seated and walking postures on motor and cognitive function tests. They used a battery of assessments which were considered to simulate office work. The test battery assessed selective attention, processing speed, typing speed, mouse clicking/drag-and-drop speed, math, and reading comprehension. Treadmill walking was associated with a 6 to 11% decrease in math problem solving success, mouse use, and typing performance, however no difference in reading comprehension, attention and processing speed were detected (John et al., 2009). Insufficient time to acclimatize to walking while working is one important limitation of the study. Acclimatisation may diminish the initial marginal decrease in work performance as seen by the effects from a treadmill workstation intervention study by Koepp et al. (2013). According to Koepp et al. (2013), who held a 1-year prospective trial using treadmill desks, work performance decreased in the first three to five months in treadmill users. The authors attributed this finding to adaptation because at completion of the study there was no significant difference in work performance between the treadmill desk workers and the non-treadmill desk workers. In a more recent 12-month long treadmill workstation intervention, Ben-Ner, Hamann, Koepp, Manohar, & Levine (2014) reported increased work quality, quantity and interaction quality when using a treadmill compared to when sitting. While computer desk work is common, there are other tasks which also need consideration in regards to performance. According to Cifuentes, Qin, Fulmer, & Bello (2015) some participants reported aspects of their jobs that were incompatible with treadmill walking such as difficulty communicating appropriate body language while dealing with sensitive issues while on the treadmill, and difficulty maintaining treadmill use due to frequently being called away to meetings. While this may be a perceived as a deterrent, the option to adopt the most appropriate posture for those specific roles is not a difficult change and also presents the opportunity for sit-stand transitions which may increase energy expenditure.
1.8.2 Energy expenditure

Compared to seated and standing workstations, treadmill desks are reported to expend the most energy (MacEwen et al., 2015; Tudor-Locke, Schuna, et al., 2014). Levine & Miller (2007) reported that obese participants ($N = 15$) expended energy at a rate of 72 kcal/hr while working at a seated desk in comparison to expending energy at a rate of 191 kcal/hr while using a walking desk at a speed of 1.77 km/hr. Unfortunately, changes in energy intake in relation to energy expenditure were not measured by Levine & Miller (2007) so an overall positive or negative energy gap cannot be determined. Increased energy expenditure is accompanied by a drive to eat and is dependent on the exercise intensity and the individuals response (Blundell, Gibbons, Caudwell, Finlayson, & Hopkins, 2015) which often leads to increased energy intake (Thomas et al., 2012). However, a negative energy gap, occurring when energy expenditure exceeds energy intake, is considered the mainstay of obesity management (Dhurandhar et al., 2015). In order to reduce sedentary behaviour without driving increased energy intake, small behaviour changes to reduce sedentary behaviour have been proposed to increase energy expenditure to such an incremental degree that minimise increases in energy intake (Hill, 2009; Hills et al., 2013). Despite no accounting for energy intake changes, results from John et al. (2011); Koepp et al. (2013); and Levine & Miller (2007) treadmill desks were associated with fat mass reduction indicating that treadmill workstations may be effective interventions to decrease obesity levels in the work place.

1.8.3 Feasibility

The decrements of work performance reported in the initial stages of treadmill workstation implementation (Ben-Ner et al., 2014) will likely incur costs for prospective businesses. With the addition of the cost of implementation (Tudor-Locke, Hendrick, et al., 2014) and maintenance of treadmill desks, the financial hurdles may be too steep for some businesses to overcome. Fidler et al. (2008) proposed that a treadmill workstation could be feasible for interpretation of radiographic images based on increased performance results. When compared to a seated interpretation, Fidler et al. (2008) reported mean detection rates out of 459 images were between 99.0% & 99.1% for the walking technique and 81.3% & 88.9% for the seated interpretations ($p = .0003$). While treadmill workstation implementation may be considered feasible for radiographic image detection, implementation in a wider variety of work settings need to be considered in order to make a substantial reduction of global sedentary behaviour. Cifuentes et al. (2015) ran a qualitative study among office workers ($N = 5$) over 6 months to identify barriers and facilitators of treadmill workstation use in a real-world setting. Participants reported having difficulty with communications when using the treadmill workstation due to the hum of the treadmill. Psychological discomfort in the form of peer pressure to maximize treadmill use along with disrespectful comments regarding the workstation by casual visitors affected participant perception of the workstation. Physical discomfort was attributed to the increased demand to maintain an upright position which subsided in most participants after 2 weeks. Furthermore, spreadsheet work performance was considered incompatible with treadmill workstations even after five months of implementation. These findings highlight the importance of real world qualitative studies in regard to workplace interventions.
Catrine Tudor-Locke et al. (2014) also conducted a study observing real-world implementation of treadmill workstations. While workers were positive about using the desks, adherence was merely 50% over a 6 month duration. The low adherence may be due to the treadmill workstations in this intervention being shared between workers and located in another part of the building. Given the expense of purchasing a desk for each staff member, it is not surprising that the researchers recommended these desks be shared. Unfortunately though, this will have minimised the success of the study given that each worker would be required to set-up their working station each time they went to use it, and as the intervention workstation was far away from their peers, participant adherence may have decreased. What this means is that selective workstation implementation may not be an effective strategy for measuring feasibility in a work setting. Furthermore, the results should be considered with scepticism as the researchers heading the study are also treadmill workstation inventors.

Participants in the Straker, Levine, & Campbell (2010) study, experienced performing office related work under six different workstation conditions including sitting, standing, walking at two different speeds, and cycling at two different speeds. Half of the participants considered workplace treadmill workstation implementation feasible. Participants reported that fine motor coordination while using a computer was disrupted by walking and that the movement of the head, relative to display, was dizzying and required enhanced concentration. The difficulty of coordinating static upper body computer tasks and a mobile lower body task, enforced by the walking platform, is a likely reason for this occurrence. Feedback on the comparisons between workstations has provided valuable information pertaining to the feasibility of each workstation.

Kline, Poggensee, & Ferris (2014) found gait stability was affected during a dual-task intervention whereby participants walked while performing a spatial working memory task. This shows that tasks requiring increased cognitive loading may pose a safety risk when walking on a treadmill. Given the health and safety laws and regulations that an employer needs to abide by, feasibility of treadmill implementation may be partially determined by the level of cognitive load required of workers.

Treadmill desk use, while effective at increasing energy expenditure, comes at a cost in regards to outlay, adherence, safety concerns, and initial performance reductions. Further investigation into the feasibility of long term treadmill workstation implementation is required to determine whether acclimatisation will decrease some of the aforementioned costs. In order to determine whether long term treadmill studies may cause harm to participants, the biomechanical effects of prolonged treadmill walking need consideration.

1.8.4. Musculoskeletal considerations

Edelson & Danoffz (1989) compared musculoskeletal pain between sitting and walking conditions and found that participants reported reduced pain in the head, shoulders, mid to lower back, buttocks and thighs after performing 2 hours of word processing at a treadmill desk. While a
slight increase in leg, foot and mild wrist pain was reported in the walking condition compared to sitting, pre-existing pain was not reported opening the possibility of re-aggravation of prior pain conditions from walking. However, pain in the wrists and legs were also reported in a more recent treadmill desk study by Straker, Levine, & Campbell (2010) which supports Edelson & Danoffz's (1989) findings and therefore indicating unfamiliarity with prolonged walking as a possible rationale for pain causation. However, wrist pain from treadmill workstation use presents a fundamental biomechanical issue that needs consideration. Thoracic movement while walking is accompanied by arm swing which helps aid biomechanical efficiency (Kuhtz-Buschbeck & Jing, 2012), which when restricted is considered to increase thoracic movement (Straker et al., 2010) and head movement. On the other hand, desk work demands a relatively static upper-body posture. In order to maintain a static position on a mobile base, there must be a junction point at which increased functional demand is required which, in treadmill workstations, appears to be in the wrists. Future workstation designs may consider ways to increase upper body mobility in treadmill workstations to help decrease wrist pain. Furthermore, as the biomechanical effect of restricting arm movement while walking is shown to increase energy expenditure compared to normal gait (Kuhtz-Buschbeck & Jing, 2012; Umberger, 2008) it is at the expense of gait stability in the form of recovery from perturbance (Hu et al., 2012; Meyns, Bruijn, & Duysens, 2013; Straker et al., 2010) highlighting issues which future treadmill workstation designs may struggle to overcome.

While fundamental biomechanical issues, which cause wrist pain, are inherent in the current treadmill workstation design, some of these issues may be decreased by future designs. As the reported lower extremity pain may be due to a lack of acclimatization, more long-term studies are required to determine approximate times for lower extremity pain to subside.

1.8.5 Treadmill workstation effect on gait and cognitive performance

The tasks of walking and working have been shown to decrease performance in both tasks due to a competition for neural resources (Straker et al., 2010). The term dual-task interference has been used to describe the performance decrement caused by these competing tasks (Hazeltine, Teague, & Ivry, 2002; Pashler, 1994). Dual-task interference, consisting of walking while performing cognitive tests, have been shown to negatively affect performance of these tasks by adults of all ages (Al-Yahya et al., 2011; Hagner-Derengowska et al., 2016; Wrightson, Ross, & Smeeton, 2016). However, older adults have poorer dual-task performance scores given their increased attention on maintaining balance while working (Al-Yahya et al., 2011; Hollman, Kovash, Kubik, & Linbo, 2007; Kline et al., 2014).

A meta-analysis conducted by Al-Yahya et al. (2011) showed that dual-task interference is affected more by complex and demanding cognitive tasks which utilize various brain regions in comparison to reaction time tasks which load lower order neurons. Visuospatial performance decrements have also been demonstrated in young adults while walking and is undifferentiated by treadmill speed (Szturm et al., 2013). However, Kline, Poggensee, & Ferris (2014) found no performance decrements of a spatial working memory task between standing and walking conditions.
As Kline et al. (2014) merely utilised one task and one level of cognitive difficulty, it is unclear whether findings were skewed by a lack of task complexity. It appears from these findings that cognitive decrement while walking may be dependent on task complexity rather than on walking itself, however differences in the width of treadmills have been found to affect tasks performance by disturbing the prioritization of motor and cognitive processes (Schaefer, 2014). Schaefer (2014) reports that when narrower bases of support are employed motor function is prioritized over cognitive function yet, on a standard base, cognitive function is prioritized. Unfortunately, the size of the treadmills were not reported in the previous studies by Szturm et al. (2013) and Kline et al. (2014) however, given the many similarities in these studies, it is likely that differing sizes of the testing treadmill may also help to explain the differing results.

Not surprisingly, the type of cognitive activity being performed during dual-tasks also affects the extent of gait variability. In particular, individuals appear to be more affected by tasks requiring executive function rather than verbal fluency tasks (Beauchet, Dubost, Aminian, Gonthier, & Kressig, 2005). This suggests that tasks requiring increased cognitive demand, such as in high profile jobs, may also increase the chance of falls.

In summary the treadmill workstation may be an effective intervention to reduce sedentary behaviour however the current designs impose fundamental biomechanical issues which may cause wrist pain which would likely decrease treadmill workstation use. Furthermore, treadmill workstations have shown initial decreases in work performance and are shown to be not suitable for work tasks which require fine motor coordination. As treadmill workstations require design adjustments to remedy current issues, other active workstation alternatives require investigation.

1.9 Cycling Workstations

Cycling workstations are workstations which have combined a seated pedal based machine, such as an ergometer or a stationary cycle, and a desk raised to a suitable working height. The cycle workstation has been suggested by Straker et al. (2010) and Carr et al. (2014) as an effective way of increasing energy expenditure in the workplace. Cycling is considered to affect health by improving aerobic fitness and raising high-density lipoprotein levels. According to Morris, Clayton, Everitt, Semmence, & Burgess (1990) who followed 9376 participants without coronary issues over 9 years, those who cycled daily were found to have less than half the amount of instances of coronary heart disease than those who didn’t cycle. Owing to these positive effects on health, further inquiry is necessary to determine the effects of cycling workstation on measures of health.

1.9.1 Effect on health

Increased daily energy expenditure in comparison to sitting makes the cycling desk an attractive intervention to consider in the workplace. Carr et al. (2014) and Elmer & Martin (2014) reported cycling desk use performed at 9 W and 38 ± 14 W increased energy expenditure by 68 kcal/hr and 155 kcal/hr respectively in comparison to seated desk energy expenditure.
Although Elmer & Martin (2014) reported an extremely positive outcome, it is difficult to draw any strong conclusions from their trial due to limited participant numbers (N=10) and a lack of real world transferability due to a ten minute intervention duration. For this reason, no extensive effects are currently known such as the dose-response effect on the musculoskeletal system, how quickly their cadence dropped, how quickly their fatigue increased or whether the intervention would induce pain potentially halting the study. Furthermore, one of the researchers is mentioned as being the inventor of intellectual property relating to a cycling workstation increasing the potential for bias.

Carr, Karvinen, Peavler, Smith, & Cangelosi (2013) completed a longer study over the course of 12 weeks and found a reduction in sedentary time by an average of 58 min/day. While no significant change in cardiometabolic risk factors (Weight, BMI, Blood Pressure, Estimated VO₂ max, Total Cholesterol, High-Density Lipoproteins, Low-Density Lipoproteins, and Triglycerides) were found, there was a significant reduction in waist circumference (p = 0.03) between intervention (−1.0 cm (−2.1 to 0.3), p = 0.06) and control groups (+1.0 cm (−0.7 to 2.7), p = 0.22). Carr et al.'s (2013) findings suggest that low intensity physical activity in the workplace may be used as part of an effective strategy to reduce some physical parameters and thereby minimise the prevalence of non-communicable diseases. However, a much longer study would need to be conducted in order to determine whether this intervention these effects are able to be either maintained or improved upon.

1.9.2 Musculoskeletal pain

Prior to consideration of cycling as a viable intervention strategy, a review of common musculoskeletal pains among frequent cyclists should be considered. Callaghan & Jarvis (1996) questioned 523 elite cyclists from track, road and mountain bike squads, and found the most common musculoskeletal complaints were low back pain (60%) and knee pain (33%). While the effects of cycling on sedentary populations may not generate the same types of musculoskeletal complaints as elite cyclists because of lower cycling intensities and differences in upper body biomechanical demands, future longitudinal studies may show some similarities between these populations due to increased cycle workstation use. Small changes to cycle setups such as adjusting seat angles (Salai, Brosh, Blankstein, Oran, & Chechik, 1999) or heights (Bini, Hume, & Croft, 2011) has been shown to improve low back pain among cycling populations. The transferability of these studies are limited due to cycle workstations demanding a more upright posture than regular cycling. However, the differences in body angles need consideration with respect to how they may effect pain patterns in conjunction with the different types of cycling desk employed. Unfortunately, owing to the infancy of cycling workstations, there is little research yet available that explores this issue even though it would provide vitally important information for prospective cycle workstation purchasers.

Of the cycling workstation studies that reported on musculoskeletal issues, participants (N = 30) in Straker et al.'s (2010) study reported hip and gluteal discomfort which was related to the seat of the cycling workstation, while participants (N = 40) in Carr et al.’s (2013) study reported that their knees kept hitting the desks and proposed that height-adjustable desks may help resolve this issue. Yet, the effects of changing the desk height will also affect wrist positioning and would likely alter
upper-limb posture and control, therefore requiring further investigation. Furthermore, while Straker et al. (2010) used a cycle ergometer with a seat attached set at popliteal height, Carr et al. (2013) used a standalone, under-desk pedal machine but did not provide any information on the type of seats employed. The difference between pedalling while using an office chair with wheels compared to a stationary chair would demand very different biomechanical and cognitive challenges. Large motion differences can be made by small seating alterations (Bini et al., 2011) let alone how these motions would differ when paired with a chair on wheels. Bini et al. (2011) found that a 5% increase in seat height affected knee joint kinematics by 35% and moments by 16%. The difference in reported types of pain between Straker et al. (2010) and Carr et al.’s (2013) studies, in combination with the large degree of biomechanical change affected by small changes to setup, expose the need for a standardised cycle workstation. It is likely that the initial the effects of cycling uptake may induce pain due to the unfamiliarity of the workstation, however these effects may diminish over time (Ben-Ner et al., 2014).

As many types of cycling workstation are used for testing, it is difficult to generalise the effects of cycling workstations on musculoskeletal pain. A standardised workstation is needed to determine whether the positive effects of cycle workstation energy expenditure outweighs any musculoskeletal issues that may arise. While the physical effects from cycle workstation use are currently difficult to determine, the effects on work performance need to be considered.

### 1.9.3 Work performance

Cycle workstations offer a more stable base of support than treadmill workstations which means that thoracic and head movements are smaller and may explain the relatively increased task performance during cycle workstation use as reported by Straker et al. (2010). Straker et al. (2010) found participants \(N = 30\) actual performance of combined keyboard and mouse task speed, while using a treadmill workstation at a pace of 1.6 kms/hr, was decreased by 15% compared to a 3% reduction of actual speed while using a cycling workstation in comparison to a seated workstation. Reduced work performance was reportedly due to seat discomfort and the difficulty of maintaining a set cycle pace during cycling compared to sitting.

Elmer & Martin (2014) measured the effect of recumbent cycling on typing time and error rate whereupon they found no difference between sitting and cycling at \(38 \pm 14\) W. On the contrary, results from a study by Cho, Freivalds, Rovniak, Sung, & Hatzell (2014) showed a significant decrease in the performance of typing and comprehension in participants \(N = 12\) using a recumbent cycle workstation at a similar intensity of 25W compared to no cycling \(F(2,22) = 19.75, p < 0.001\). No significant difference was found between low intensity cycling (10W) and no cycling \(p = 0.179\) however, serious limitations are not addressed within the study which may have influenced results. There were concerns surrounding the equipment set-up, which consisted of a mobile (wheeled) office chair connected to a Velcro strap which was then connected to a pedal ergometer. This begs the question as to how stable the participants felt using the set-up which may have required excess difficulty in maintaining the seat to pedal position (particularly at higher intensities) adding an
unaccounted variable. This may have also affected performance in favour of maintaining stability. In
comparison, the ergometer used by Elmer & Martin (2014) was connected from seat to pedals by a
metal frame reducing the likelihood of stability issues. This may help to explain the variance between
results in the two studies. Commissaris et al. (2014) measured the effects of two cycle workstations
on work performance, an upright cycle ergometer and a semi-recumbent cycle workstation. Both cycle
workstations had seat and pedals that were joined by a sturdy frame and cycle workstation conditions,
at low and high cycling intensities (25% HRR: 56 ± 21 W and 40% HRR: 85 ± 28 W), displayed no
effect on typing performance. However, mouse performance decreased 6-8% during both cycling
intensities, and errors increased 42% (at 25% HRR) and 68% (at 40% HRR) in comparison to sitting.
Mouse performance appears to be negatively affected by increased cycling speed and maintaining
speeds. To determine whether mouse performance is negatively affected by attention to maintaining a
set speed, studies which compare mouse performance while performing cycling at self-selected and
set speeds are necessary.

The variations between the workstation designs in each study highlight the difficulty of
generalising cycle workstation work performance results. While cycle workstation stability appears to
produce less variance in typing performance, lower cycling speeds have shown to produce better
mouse performance. Future research on cycling workstations which incorporate stability and self-
selected cycling speeds will improve the current status of cycle workstation work performance. What
this means is that the full extent of work performance is yet to be discovered in cycling workstations
and so it is worth inquiring whether participants find cycle workstations a feasible alternative to
traditional seated workstations.

1.9.4 Feasibility

A lack of cycle workstation standardisation combined with few studies which have measured
feasibility of cycling workstation use makes it difficult to draw conclusions of feasibility. Straker et al.'s
(2010) study used a cycle ergometer and found that 63% of participants (N = 30) considered cycling
desks were practical, while 13% were less enthusiastic about their use. As Straker et al.'s (2010)
study measured sitting, standing, cycling and treadmill workstations, comparisons were made
between interventions. While participants reported experiencing improved balance and less upper-
body movement with cycling relative to the walking intervention, negative aspects of the cycling
intervention consisted of seat discomfort and the distraction from work while trying to maintain a set
cycling speed. Further difficulties may be encountered in a real-world setting, and as Straker et al.'s
(2010) study was conducted in a laboratory, real-world psychosocial aspects of feasibility were not
measured which has been shown to be a potential barrier of active workstation use (Cifuentes et al.,
2015).

Carr, Karvinen, Peavler, Smith, & Cangelosi (2013) compared the differences in compliance
between the cycling intervention groups, a motivational intervention group (n = 23) and a non-
motivational intervention group (n = 18). They found that compliance improved by 8 minutes per day
when a motivational intervention was performed. Participants reported that the feedback from the
pedal machine tracking software, pedometers and ability to self-monitor daily activity online were the most helpful features for reducing their daily sedentary time (Carr et al., 2013).

Cycle workstations are an attractive option for workplace intervention due to reductions in waist circumference and sedentary behaviour, high participant approval rates and a high level of compliance. However, conflicting and unreliable work performance results indicate that longer duration studies are needed to measure work performance changes over time with a standardised cycle workstation. While the future of cycling workstation implementation looks promising, a lack of information regarding the musculoskeletal effects of using a cycle workstation need longitudinal research in various office roles in order to assess the types of biomechanical stresses associated with cycle workstation use.

1.10 Standing and sit-stand workstations

Standing workstations require users to stand upright at a desk which is raised to working height. Height-adjustable desks are a common theme appearing in most active workstation studies reviewed thus far. In order to assess whether the costs of including a treadmill or cycle intervention to a height adjustable desk are advantageous to the potential user, inquiry into the effects of standing workstations are necessary. While a systematic review by MacEwen et al. (2015) describes a large evidence gap for reducing sedentary behaviour in the workplace by using standing and treadmill workstations, more recent literature may help mend the knowledge gap. MacEwen et al.’s (2015) last month of data mining was June 2013 and since then, progressive interest in active workstations has sparked further research has expanded the knowledge base of active workstations (Shrestha et al., 2016).

Sit-stand workstations also utilise a height-adjustable desk enabling users to sit or stand so as to encourage postural variation and may be considered as a more active version of standing workstations. There are likely differences between standing and sit-stand desks however MacEwen et al.’s (2015) review combined results from standing and sit-stand workstation studies meaning the effects of either intervention in this review are not clearly outlined. Furthermore, according to a Cochrane review by Shrestha et al. (2016) a limited amount of research is available for active workstations with most studies utilizing sit-stand interventions. Perhaps owing to the increased weighting of sit-stand studies amongst a low amount of combined active workstation studies, current systematic reviews (MacEwen et al., 2015; Shrestha et al., 2016, 2015) report that sit-stand workstations are an effective workplace intervention to reduce total sitting time.

While current reviews may not help in determining the effectiveness of standing on reducing sedentary behaviour in the workplace, further inquiry utilizing the most current literature is warranted to determine effects of standing workstation implementation.
1.10.1 Health effects

The majority of studies investigating the difference in energy expenditure between standing and seated work conditions report that energy expenditure is increased in standing postures (Beers, Roemmich, Epstein, & Horvath, 2008; Benden, Zhao, Jeffrey, Wendel, & Blake, 2014; Cox et al., 2011; Reiff, Marlatt, & Dengel, 2012). Carter et al. (2015) reported an increase of 3 kcal/hr of energy expenditure in a standing condition for a duration of 2 minutes per hour, compared with sitting. However, these findings were not significant which is unsurprising due to the low standing duration.

While contradictory evidence reported by Speck & Schmitz (2011) has shown no difference in energy expenditure or METs between seated desk work, stability ball desk work, and standing desk work, the methodological quality of this study is reportedly low due to lack of detail in the manuscript (MacEwen et al., 2015). Specifically, Speck & Schmitz (2011) did not report the duration of the intervention, the intervention order, and the time between interventions. Levine et al. (2005) conducted a pilot study measuring time spent in sedentary behaviours between lean (BMI = 23 ± 2 kg/m2) and obese (BMI = 33 ± 2 kg/m2) participants by using an accelerometer. While obese individuals sat for an additional 164 minutes per day, lean individuals stood for an additional 152 minutes per day. While Levine et al. (2005) estimated that standing may elicit energy expenditure at a rate of 350 Kcal/day in obese individuals, Miles-Chan, Sarafian, Montani, Schutz, & Dulloo (2013) argues that <20 kcal/day is more likely to be expected. However, Miles-Chan et al.’s (2013) sample merely included healthy lean individuals (BMI = 22 ± 1 kg/m2) and therefore results are not comparable with Levine et al.’s (2005) study as increased weight demands increased energy expenditure to move (Westerterp, 2013). Furthermore, Miles-Chan et al.’s (2013) study used a motionless standing intervention while Levine et al. (2005) measured normal postural changes in participants which may further explain the difference between results. While further scrutiny of the energy expenditure difference between sitting and standing is necessary, addressing the target sample in real-world settings is just as important as it may generate more applicable results.

Alkhajah et al. (2012) conducted a pilot study measuring the effects of a sit-stand workstation intervention on fasting total cholesterol, HDL cholesterol, triglycerides and glucose levels. These measures were taken at baseline, 1-week and 3-month intervals. Participants were from academic institutions and were assigned to either an intervention group (n = 18) or a control group (n = 14) with both groups being instructed to go about their daily tasks as usual. The intervention group had a sit-stand workstation installed, with brief verbal instructions of use as well as written instructions on correct ergonomic setup and the benefits of frequent postural change. All participants wore an accelerometer to measure postural transitions. At 3 months, the intervention group showed increased HDL cholesterol by an average of 0.26 mmol/L (95% CI = 0.10, 0.42) and while other biomarker differences were not significant, sitting time was reduced by 27%. Healy, Winkler, Owen, Anuradha, & Dunstan (2015) recently published a study which offers more robust findings due to a larger data pool regarding the effect of standing on cardiometabolic markers. In this study it was shown that participants (N=698) displayed significantly (p < 0.05) lower fasting plasma glucose (2%), lower triglycerides (11%), lower total / HDL-cholesterol ratio (6%), and higher HDL-cholesterol (0.06 mmol/L) per 2-hr/day after standing over a duration of 7 days. However, Bailey & Locke (2015) found
that a short 2-minute bout of standing every 20 minutes, over 5 hours was no different than
uninterrupted sitting in total cholesterol, HDL, triglyceride levels or systolic and diastolic blood
pressure ($p > 0.05$) in participants ($N = 10$). Furthermore, Miyashita et al. (2013) also found no
postprandial lipaemia reduction in participants ($N = 15$) after they stood for 45-minute intervals every
hour for 6 hours per day for two days in comparison to sitting. While the effects of standing on
physiological measures are contentious based results from the aforementioned studies, the duration
and sample sizes of both Healy et al. (2015) and Alkhajah et al.’s (2012) studies far exceed those of
Miyashita et al. (2013) and Bailey & Locke (2015) increasing the likelihood that standing improves
cardiometabolic markers. Interestingly, when Takahashi, Miyashita, Park, Sakamoto, & Suzuki (2015)
utilized the same blood samples from participants in Miyashita et al.’s (2013) study, oxidative stress
levels were found to be elevated the day after the sitting intervention while no change was noted in
the standing intervention. As acute exercise has also been found to improve oxidative stress levels,
increased physical activity may explain improved stress levels in standing. Therefore, future research
into standing durations exceeding those in Miyashita et al.’s (2013) study may possibly show
reductions in oxidative stress levels.

In summary, standing seems to have a positive effect on cardiometabolic markers. Larger
samples and longer study durations may provide a better understanding of the longitudinal effects of
standing which would likely be included in future work health guidelines. While the effects of standing
on cardiometabolic health markers are favourable, the effects of prolonged standing on
musculoskeletal pain need consideration to gauge the feasibility of implementation.

1.10.2 Musculoskeletal pain

According to some self-report studies, standing appears to be a favourable short-term
intervention strategy to help reduce musculoskeletal pain compared to sitting (Husemann et al., 2009;
Pronk, Katz, Lowry, & Payfer, 2012; Straker et al., 2010). Positive results have included reduced
upper-back and neck pain (Graves et al., 2015; Pronk et al., 2012), while decreased activation of the
upper extremities was reported by Lehman, Psihogios, & Meulenbroek (2001) which equates to a
decrease in functional demand and likely would equate to lesser instance of upper extremity and neck
pain over longer durations. However, negative results pertaining to prolonged standing also exist
showing increased pain in the legs (Straker et al., 2010), low back, ankles and feet (Messing, Stock,
Côté, & Tissot, 2014). According to reviews by Messing et al. (2014) and Neuhaus et al. (2014),
ambiguity and variations of the standing position create difficulty when attempting to determine the
associated health impact. The number of steps or position shifts a participant may perform, within the
confines of these studies, may limit transferability of results to real-world office settings.

McCulloch (2002) found that when summarising data on 17 studies, standing for durations of
8 hours or longer was associated with musculoskeletal dysfunction in the lower back and feet, and
of prolonged standing among participants without a history of low back pain. Here, participants
performed an unloaded squat, single leg stance and lumbar flexion test before and after 2 hours of
uninterrupted standing. Low back pain developed in 40% of participants during the intervention while
dehcreased vertebral rotation, stiffness in lateral bending and increased centre of pressure excursion
were measured during the unilateral stance after prolonged standing. This suggests that static
standing may contribute to musculoskeletal dysfunction.

Sit-stand workstations are considered to provide an alternative to static work postures that
may also help to ameliorate the negative health effects caused by staying on one place for extended
periods of time (Husemann et al., 2009; Karakolis & Callaghan, 2014; MacEwen et al., 2015; Messing
et al., 2014). Callaghan & McGill (2001) found participants (N = 8) displayed different spinal
curvatures between 2 hours of prolonged sitting versus standing. Interestingly, EMG results displayed
higher activation levels of the upper and lower erector spinae while in the seated posture. Callaghan
& McGill (2001) also found that sitting increased the compressive forces of the spine, pointing out the
positive effects of motion on intervertebral disc nutrition. The importance of frequent adjustments to
the spine while seated can be seen as one way to preserve intervertebral disc health. These findings
display the positive effect that frequent postural change can have on the musculoskeletal system.

Robertson et al. (2013) reported that participants who received ergonomic training had
reduced musculoskeletal symptoms located in the neck, shoulders and lower back and reduced visual
symptoms such as blurring and difficulty focusing compared to those with minimal training. While
symptoms arose earlier among the minimally trained group than the ergonomically trained group and
persisted throughout the duration of the study, symptoms in the ergonomically trained group were
reportedly minimal throughout the study and were close to non-existent by the end of the study. This
shows that workstation studies require ergonomic support in order to reduce musculoskeletal
complaints and acclimatization time in order to determine the actual effectiveness of an unfamiliar
workstation.

While static postures such as prolonged sitting or standing appear to increase
musculoskeletal complaints, the variability of postures enabled by sit-stand workstations appear to
decrease these complaints especially when ergonomic support and sufficient acclimatization time is
provided. The aforementioned benefits of sit-stand workstations provide rationale for investigating the
effects on work performance in order to address the feasibility of these interventions in the workplace.

1.10.3 Work performance

A recent systematic review by MacEwen et al. (2015) reports that work performance is stable
and without decrement over time while working at a standing desk. Furthermore, no significant
difference has been found between sitting and standing postures when measuring various aspects of
work and cognitive performance such as speech quality (Cox et al., 2011); signal detection tasks
(Drury et al., 2008); computer-based transcription (Ebara et al., 2008); basic multiplication tasks
(Hasegawa et al., 2001); stroop colour word test, auditory consonant trigram test, and digital finger
tapping test (Ohlinger et al., 2011); data entry efficiency (Husemann et al., 2009); typing performance, mouse performance and combined keyboard and mouse task performance (Straker et al., 2010).

Chau et al. (2016) conducted a study to measure objective and subjective productivity among call-centre workers \((N=31)\) using a sit-stand desk. Participants wore accelerometers and were assigned to either a sit-stand workstation \((n = 16)\) or a seated workstation \((n = 15)\). Performance measures included work specific tasks such as talk time, hold time and absenteeism over the 19-week duration. No changes to productivity were observed between groups, yet at 19 weeks sitting time had decreased in the sit-stand group by 100 minutes per day. The main strengths of this study was that it was conducted in a real world setting using job specific measures and had strong engagement with upper-level management throughout the planning, intervention and evaluation stages. This study displays that effective workstation implementation is possible as noted by the successful decrease in workplace sedentary behaviour which may be attributed to the company’s investment in carefully managing and facilitating the workstation’s implementation.

Robertson et al. (2013) observed the performance effects when taking one group \((n = 11)\) through ergonomic training on how to use a sit-stand desk compared to another group \((n = 11)\) who were minimally trained to use the sit-stand desks. This was measured by the accuracy and quantity of faxed customer forms entered into a computer during a simulated customer service role. While no significant difference in fax quantity was found between groups, fax accuracy was significantly improved in the ergonomically trained group in comparison to the minimally trained group over all 15 study days \((F(1, 20) = 5.3, p = .03)\). If correct ergonomic setup can improve work performance, then more real world studies are needed to strengthen this finding.

Husemann et al. (2009) found a small trend toward data entry performance decrement during a sit-stand workstation intervention. However, as participants \((N = 60)\) were merely measured for 4 hours per day for 5 consecutive days, these slight decreased performance effects may be attributable to acclimatization of the workstation (Ben-Ner et al., 2014). Interestingly, Ebara et al.’s (2008) study showed that participants \((N = 24)\) displayed steady performance while performing computer-based English transcription for a duration of 150 minutes at a sit-stand workstation. However, performance while sitting displayed a decline over time which may be due to the lack of arousal attributed to sitting. The performance differences between these aforementioned studies require further investigation as both data entry and transcription tasks require the movement of information from one place to another. The time spent performing each of these tasks and the duration of the studies were different with standing workstation performance being negatively affected by increased time on task. This finding may appear to indicate an effect from fatigue however, Husemann et al. (2009) also took baseline and post study measures of fatigue and found no difference between sitting and sit-stand groups. Despite the slight performance differences in these aforementioned studies, sit-stand workstations show no decrement to work performance. What this means is that sit-stand workstations are an effective intervention to reduce workplace sedentary behaviour without performance
decrement. Owing to this finding, it is necessary to determine participant responses to the use of sit-stand workstations.

1.10.4 Feasibility

Habituation of seated desk use is promoted from a young age. A large foreseeable barrier to standing desk implementation may be due to the difficulty of suppressing the habit of seated desk work under demanding cognitive loads (Aarts & Dijksterhuis, 2000). However, Aarts & Dijksterhuis' (2000) findings promote a conditional automaticity of habits with which, provided the goal of utilizing standing workstations is strong enough, habitual use of standing desks may be achieved.

According to Straker et al. (2010), implementation of standing desks in the workplace was reported as feasible by 83% of participants (N = 30) while feasibility of cycling or walking desks were reported as 63% and 50% respectively. Hinckson et al. (2013) studied the acceptability of a standing desk intervention among elementary school students (N = 23) over a period of 3 months. The implementation and use of the desks were met with positivity by students, parents and school staff throughout the study and remained in continued use after study commencement. Furthermore, Grunseit, Chau, van der Ploeg, & Bauman (2013) found that standing desks were likely to be used by participants (N = 31) regardless of extrinsic prompting. As both manual and electric desks were used in the Grunseit et al. (2013) study, the electric desks were associated with more frequent changes in desk height. Less frequent users of the standing desks in Grunseit et al.'s (2013) study attributed lack of use to not enough set-up instruction which reflects the same findings in Wilks, Mortimer, & Nylén (2006) and Robertson et al.'s (2013) studies.

Following a thorough review of the literature it has become apparent that sit-stand workstations are considered to be a feasible workstation alternative to sitting. There is also a growing consensus that energy expenditure, musculoskeletal pain, and cardiometabolic markers are improved by the use of sit-stand workstations without decrement to work performance. Despite these encouraging findings for the more practical and physiological aspects of their use, their effect on cognitive performance is still lacking.

1.11 Cognitive Performance

Cognitive performance refers to our ability to acquire and utilise knowledge. As cognitive ability is considered to predict work performance (Alexander, 2007; Hunter, 1986), the testing of cognitive performance under different conditions may provide information regarding the effects of conditions on work performance. While work performance is beneficial for job specific measures, in order to determine effects across a wide range of jobs, the variance of cognitive loading between work performance measures is too wide to determine effects. The benefit of measuring the effects of conditions by using cognitive performance in favour of work performance is that cognitive tests are usually standardised and therefore likely to increase the homogeneity of findings between studies. This means that in order to determine the effects of workstation interventions throughout a wide range jobs, cognitive performance seems like the most appropriate measure.
Nilsson, Tovar, Johansson, Radeborg, & Björck (2013) found that cognitive performance could be improved by reducing markers of cardiometabolic risk factors due to following an anti-inflammatory diet. Therefore if cardiometabolic risk markers influence cognitive performance and sedentary behaviour is linked with increased cardiometabolic risk markers then studies which measure cognitive performance in active workstations are necessary to improve the current state of global health.

While the testing of cognitive performance in active workstations has thus far been conducted on the cognitive domains of Attention, Working Memory, Processing Speed (Bantoft et al., 2015), and Executive Function (Schraefel et al., 2012), the effects on Perceptual Reasoning performance have not currently been conducted. Perceptual Reasoning is one of the four primary testing domains set out in the Wechsler Adult Intelligence Scale IV (WAIS-IV). As the WAIS-IV is one of the most frequently used intelligence scales worldwide (Lichtenberger & Kaufman, 2009), the effects of variables which affect the performance of these domains require investigation.

In summary, the effects of active workstations on cognitive performance warrant investigation to help understand whether these interventions may affect work performance. The effect of these workstations on the Perceptual Reasoning domain demands the greatest inquiry due to the current absence of research. In order to determine whether an effect may be expected, a closer look at related constructs is necessary.

1.11.1 Perceptual reasoning and closely related constructs

Perceptual Reasoning is a component of cognitive performance which refers to an individual’s ability to apply reasoning with non-verbal, visual stimuli (Lichtenberger & Kaufman, 2013). The Perceptual Reasoning Index helps determine the extent of a participant’s ability to utilise multiple cognitive processes to successfully solve a problem (Holdnack, Drozdick, Weiss, & Iverson, 2013). This helps to identify a participant’s level of proficiency in solving problems immediately versus using accumulated knowledge. People with a higher Perceptual Reasoning Index may exhibit increases in abilities such as correctly assembling objects, following maps, estimating distance and accuracy of driving from one place to another (Groth-Marnat, 2009). According to Barrett, Barrett, & Williams (2003), Perceptual Reasoning is one of the foundations of scientific thinking, requiring the individual to build concepts and prove theories and therefore an important ability in the roles of researchers and scientists.

The primary constructs that are targeted for assessment in the Perceptual Reasoning Index include (a) reasoning with visually presented non-verbal stimuli; (b) reasoning with visual quantitative information; (c) reasoning with conceptually related concrete visual stimuli; (d) reasoning with conceptually related abstract visual stimuli; and (e) reasoning about how to integrate visual elements to create a model (Lichtenberger & Kaufman, 2013).
Some correlation has been found between cognitive domains within the WAIS-IV and abilities outlined in the Cattell-Horn-Carroll (CHC) theory of cognitive abilities. When testing comparisons between Perceptual Reasoning tasks and CHC abilities, Fluid Reasoning tasks are considered to bear the closest comparison (Duncan, Burgess, & Emslie, 1995; Roca et al., 2010; van Aken et al., 2015) while Matrix Reasoning tasks are the most correlative within WAIS-IV measures (Weiss, Keith, Zhu, & Chen, 2013). While some Perceptual Reasoning Index tasks load more heavily on one cognitive factor it is important to consider that multiple cognitive factors are being tested in each task concurrently and as such, the communication between these factors may be as influential as the cognitive factors involved in the perceptual reasoning tasks (Drozdick, Holdnack, Weiss, & Zhou, 2013).

Fluid Reasoning is considered to encompass inductive, deductive, and quantitative reasoning, the acquisition of knowledge through reasoning, and the speed of reasoning (McGrew, 2009). From a young age the utilization of Fluid Reasoning ability can be observed when learning occurs through complex abstract relations such as completing puzzles (Ferrer, O'Hare, & Bunge, 2009). The pervasive nature of Fluid Reasoning may be observed by correlations with general intelligence performance (Blair, 2006; Valentin Kvist & Gustafsson, 2008; van Aken et al., 2015) and performance in other domains of cognitive function (Duncan et al., 1995; Roca et al., 2010) especially working memory and executive function (Ferrer et al., 2009).

Working Memory and Fluid Reasoning performance have been considered to be near identical when time constraints have been applied. Interestingly, a study by Colom et al. (2015) found that Fluid Reasoning and Working memory performance correlated ($r = 0.86$) regardless of time constraints in participants ($N = 302$) and is a finding supported by other studies (Engle, Tuholski, Laughlin, & Conway, 1999; Kane et al., 2004; Redick, Unsworth, Kelly, & Engle, 2012; Unsworth, Fukuda, Awh, & Vogel, 2014). The correlation between the two cognitive abilities, as proposed by Colom et al. (2015), may be due to utilization of general mechanisms relating to the reliability of short-term memory storage while concurrently processing information. While the aforementioned mechanism is plausible, Chuderski (2015) considers that the 40 minutes of testing time used in Colom et al.’s (2015) study did not allow participants enough time to measure Fluid Reasoning in the untimed tasks. Chuderski (2015) measured a testing time of at least 60 minutes, finding the largest difference between Working Memory and Fluid Reasoning performance in the more complex tasks whereas the easy and moderate complexity tasks displayed more similar results and were more attributable to Working Memory performance. Interestingly, when time restraints were engaged there was no longer much difference between Working Memory and Fluid Reasoning performance. Chuderski’s (2013, 2015) findings help explain the conclusion from a longitudinal study by Greiff et al. (2015), that Fluid Reasoning performance is a stronger predictor of complex problem solving performance than Working Memory performance. There appears to be inconclusive evidence to base how relaxed time constraints need to be in order to determine when engagement of Fluid Reasoning succeeds Working Memory performance. The recommendation regarding timing of Perceptual Reasoning Index tasks by Lichtenberger & Kaufman (2013) is that all Perceptual Reasoning Index tasks are timed by stopwatch.
except for the Matrix Reasoning task which has no time limit, however a response is encouraged after
30 seconds per item.

In summary, Perceptual Reasoning tasks require the use of non-verbal abstract relational
problem solving skills which are particularly necessary for the initial stages of learning. Perceptual
Reasoning tasks are correlated with other cognitive abilities and domains including Fluid Reasoning,
Working Memory and Executive Function. This infers that studies showing performance effects in
these domains may also be considered to affect Fluid Reasoning and Perceptual Reasoning domains.
In the case of Working Memory, performance similarities may be more or less determined by the
degree of complexity amongst tasks and whether time pressure is involved. As cognitive performance
may be affected by different variables, such as active workstation intervention, knowledge of the
variables which affect Perceptual Reasoning need to be investigated.

1.11.2 Variables affecting perceptual reasoning Index performance

As Perceptual Reasoning Index utilizes visual components and reasoning, it is considered an
inaccurate measure of intelligence in people who have neurological, developmental, or medical
conditions that affect their visual processes. Additionally, impaired motor function will also affect
performance of the Block Design test from the Perceptual Reasoning Index (Holdnack et al., 2013).
While Perceptual Reasoning Index performance will be compromised by spatial processing disorders,
such as Turner’s syndrome (Kesler et al., 2004; Messina et al., 2007), Perceptual Reasoning Index
performance has not been found to be significantly affected by Attention Deficit Hyperactivity Disorder
(Holdnack et al., 2013) despite tasks requiring a certain amount of attention. While the overall effect of
age on cognitive functioning indicates a general decline as age progresses from 60 years onwards
(Salthouse, 2006), there is an effect of sex on cognitive performance. Gender has been correlated
with performance in different aspects of Perceptual Reasoning such as perceptual organization in
which males tend to outperform females (Gur et al., 2012; Van der Sluis et al., 2006) while females
outperform males in perceptual speed (Gur et al., 2012). Therefore, it is likely that Perceptual
Reasoning Index performance differences would occur between sexes and various ages.

There appears to be a relationship between physical activity and reasoning ability. Smith et al.
(2010) measured the effects of aerobic exercise on tasks related to perceptual reasoning
performance and found moderate task performance improvements however, the effects on working
memory were inconsistent. A meta-analyses conducted by Kelly et al. (2014) shows significant
improvements in reasoning performance can be achieved after performing resistance exercise in
comparison to stretching / toning exercise ($Z = 2.97, p < .005$) but not in working memory or attention.
These aforementioned studies indicate that while increased physical activity can improve Perceptual
Reasoning performance, the effects on cognitive abilities related to Perceptual Reasoning are not the
same. However, the effects of variables influencing cognitive performance in general need to be
considered due to the lack of information on variables affecting Perceptual Reasoning performance
specifically.
Cognitive performance may also vary depending on the time of day in which an individual is tested (Hidalgo et al., 2009; Randler & Bausback, 2010; Schmidt, Collette, Cajochen, & Peigneux, 2007; van der Heijden, de Sonneville, & Althaus, 2010). Van der Heijden, de Sonneville, & Althaus (2010) conducted a study measuring time-of-day effects on cognitive performance among 10 - 12 year old children and found that visuo-spatial and Working Memory task performance decreased during tasks requiring greater cognitive demand during the early morning compared with early afternoon performance. According to Schmidt, Collette, Cajochen, & Peigneux (2007), circadian arousal mediates the fluctuation of cognitive performance throughout the day and can be inter-individual. This means that cognitive performance should be tested throughout all parts of the day and therefore, the effects of cognitive performance under the effects of fatigue need consideration.

Fatigue is an important biological process that signals the body to rest however may also lead to various disease states under prolonged or accumulated stresses (Nozaki et al., 2009). Fatigue can impair both physical function, in the form of reduced force production and proprioception by affecting the joint position sense; and cognitive function by impairing the executive functioning of motor performance (Abd-Elfattah, Abdelazeim, & Elshennawy, 2015). Mental fatigue is a common occurrence following prolonged cognitive engagement (Boksem & Tops, 2008; Gergelyfi, Jacob, Olivier, & Zénon, 2015; Marcora, Staiano, & Manning, 2009) and has been found to affect both cognitive and physical performance (Marcora et al., 2009). The extent of effect that mental fatigue has over these domains of performance varies. In a study by van der Linden, Frese, & Meijman (2003), participants (N = 58) performed poorer in a mentally fatigued state during tasks loading in executive control than when performing tasks during a non-fatigued state. Surprisingly, no difference was found between fatigued and non-fatigued states during performance of simple memory tasks. According to Rozand, Lebon, Papaxanthis, & Lepers (2015) mental fatigue may slow movement in favour of preserving task success. Rozand et al. (2015) found that while mentally fatigued participants managed to complete a goal-directed arm movement task they took 4.1 ± 0.7% longer to achieve it compared to their non-fatigued counterparts. While the negative effects of mental fatigue on physical performance may occur in submaximal physical tasks, no performance deficits have been found in maximal anaerobic (Martin, Thompson, Keegan, Ball, & Rattray, 2015) and repeated high-intensity exercise (Duncan, Fowler, George, Joyce, & Hankey, 2015) interventions. As active workstation use generally requires sub-maximal exercise intensity, tasks which induce mental fatigue may impair performance of active workstation use and may pose a safety risk.

It is worth noting that the assessment of fatigue is based on subjective information and as such is measured in various self-report scales and questionnaires. Dittner, Wessely, & Brown (2004) points out that while there are numerous fatigue scales available to choose from, not one scale will be appropriate for all purposes and therefore the choice of scale is preferential. According to Wood, Magnello, & Jewell (1990), the visual analogue scale (VAS) is a reliable indicator of self-reported fatigue. The use of such a scale is considered unidimensional which is useful in obtaining a quantitative score (Dittner et al., 2004) and as such would be useful in the current research without
consuming valuable testing time. Quantitative feedback of fatigue levels in active workstation studies would help in determining whether performance effects are caused by fatigue or by the workstation.

In summary, Perceptual Reasoning performance may be negatively influenced by neurological, developmental, or medical issues affecting visual processes. Performance may be affected positively or negatively by variables such as age, sex, time of day, and fatigue levels. Furthermore, the effects of resistance exercise has been attributable to performance increases in Fluid Reasoning in comparison to aerobic exercise. Variables which are considered to negatively influence Perceptual Reasoning performance need to be controlled for when measuring the effect of active workstation use. As there is currently no research which details the effects of active workstations on cognitive performance, the effects of physical activity on cognitive performance need investigating.

### 1.11.3 Effect of physical activity on cognitive performance

Cognitive performance is considered to be positively affected by physical activity regardless of age (Hogan, Mata, & Carstensen, 2013) and current fitness level (Chang et al., 2014). Interestingly however, it has been suggested that there may be a dose-response for both children (Singh, Uijtdewilligen, Twisk, van Mechelen, & Chinapaw, 2012) and adults (Liu-Ambrose, Nagamatsu, Voss, Khan, & Handy, 2012) however future research is necessary.

Moderate-intensity resistance exercise has been demonstrated to have positive effects on Executive Function performance when performed once-weekly (Liu-Ambrose et al., 2010). Furthermore, resistance exercise performed twice weekly is found to improve flanker test performance and hemodynamic activity in the cerebral cortex (Liu-Ambrose et al., 2012). These changes are attributed to the physiological effects of resistance training which include reduced Homocysteine levels, which is an amino acid associated with vascular dysfunction (Vincent, Braith, Bottiglieri, Vincent, & Lowenthal, 2003); while increasing levels of Insulin-like Growth Factor 1, a mediator between exercise and Brain Derived Neurotrophic Factor, to help stimulate neurogenesis (Cassilhas et al., 2007).

Acute bouts of exercise have been shown to have a small, but positive effect on cognitive performance (Chang, Labban, Gapin, & Etnier, 2012) with improvements found during exercise ($g = 0.101$; 95% confidence interval [CI]; $0.041 – 0.160$), immediately after exercise ($g = 0.108$; 95% CI; $0.069 – 0.147$) and also following a significant delay after exercise ($g = 0.103$; 95% CI; $0.035 – 0.170$). Chang et al. (2014) furthered this research and found that while all fitness levels cognitively benefitted from the exercise, those who reported having a medium level of fitness displayed higher cognitive performance than those who either had low or high fitness levels. Based on these findings, we may expect to find improved scores from participants with a medium fitness level

In summary, physical activity positively affects cognitive performance yet dose-response relationships are still to be determined. Importantly, positive cognitive performance effects have been
reported to occur during physical activity promoting the rationale for testing cognitive performance during an active workstation intervention.

1.11.4 Workstation effect on perceptual reasoning performance

While the effect of active workstations on work and cognitive performance thus far have shown decrements in cycling and treadmill workstation performance, standing and sit-stand workstations have shown performance similar to sitting (Bantoft et al., 2015; Russell et al., 2015) and may even demonstrate improvements over sitting workstations in long-term studies due to the effects of acclimatization. However, not all cognitive domains have been tested as no current studies have measured the effects of these workstations on Perceptual Reasoning performance. While sit-stand workstations are reported to provide the greatest levels of performance amongst active workstations (Shrestha et al., 2016, 2015) some studies have shown performance decrements (Schraefel et al., 2012).

Schraefel, Jay, & Andersen (2012) used a cognitive testing battery of Executive Function, Complex Attention, Cognitive Flexibility, Psychomotor Speed, Reaction Time, and Processing Speed on male participants, none of whom were currently using standing desks. The authors found significantly increased performance in Complex Attention during the seated condition, while performance in all other tasks were unremarkable between conditions. Limitations within the methodology of the study may have influenced results. The study used laptop computers to test cognitive performance and despite attempts to adjust workstations to an ergonomic height fundamental issues still needed addressing. Laptop use in a standing position alters the screen and head position forcing increased neck flexion and a screen that faces lighting which increases the chance of light reflection and may have affected task performance. As both conditions were tested on each participant in 1 hour 10 minutes and included a 10 minute break between interventions, the duration appears to be far too short to determine any meaningful effect. Furthermore, the decreased performance during the standing condition may have been due to insufficient acclimatization time. There was no control for the time of day in which tests were administered, which has been considered to influence cognitive performance results within individuals (May, 1999; Schmidt et al., 2007). If the testing duration of each condition lasted a whole working day the time of day effects may have been reduced.

Bantoft et al. (2015) measured the effect of standing in comparison to seated postures on cognitive performance in undergraduate students (N = 45). Participants performed a test battery for 1-hour in duration each day for five consecutive days with no statistically significant difference found between the conditions. Russell et al. (2015) carried-out a similar study design but with University staff (N = 36) and also found no significant difference between conditions. These aforementioned studies may be improved by controlling for time of day effects, which may be achieved by testing throughout a whole day.
1.12 Overall Summary and Objectives of the Current Study

Increasing prevalence and impact of non-communicable diseases are a global threat that require a multi-factorial approach. As increased sedentary behaviour is considered to be a major health risk, interventions which aim to reduce this behaviour are needed. The majority of modern human sedentary behaviour is accumulated in the workplace in seated desks and the promotion of more active workstations is considered to be an effective strategy to decrease sedentary behaviour. However, there are strengths and weaknesses to each of the currently proposed active workstations. While the standing or sit-stand desk is not considered the most active of all the workstations, it is reported to be the most feasible, is considered to expend greater energy than sitting, has comparable work performance to sitting, and may reduce pain attributed to prolonged sitting. For this reason the current research focussed on standing desks.

Despite the proposed benefits from standing desk interventions, the effects of standing on cognitive performance has been paid little attention and requires further research. There are no current studies that have measured the effect of standing posture on Perceptual Reasoning performance explicitly, and no study has measured the effects of standing on cognitive performance throughout a whole day of testing so as to emulate the office setting.

Further studies are required to compare Perceptual Reasoning performance effects between sitting and standing workstations under workplace conditions to improve the transferability of results to real world applications. The importance of testing Perceptual Reasoning while using a standing workstation is largely due to the unknown effects that standing imposes on Perceptual Reasoning performance. By testing Perceptual Reasoning performance at a standing workstation, crucial information can be attained that may aid in guiding those undergoing future considerations of standing workstation establishment in workplaces globally.

The current study was part of a larger project that aimed to investigate the effect of standing in comparison to seated work positions on cognitive performance over the course of two 7.5 hour simulated working days, with the intention of increasing real world applicability. This study examined data collected from three tasks utilising Perceptual Reasoning that were adapted from the Wechsler Adult Intelligence Scale (WAIS-IV). The study design utilised a repeated measures cross-over design in order to best ascertain any true cognitive differences in performance between standing and sitting within participants. Performance was assessed at three different sessions throughout the day (Morning, Midday and Afternoon) and participants’ perception of fatigue was also measured at the conclusion of these sessions.
Chapter 2: Methods

2.1 Design

The current study used a randomised, controlled, repeated-measures crossover design, implemented over two non-consecutive days, with a washout period of approximately one week. Participants were randomly assigned to one of two groups, either sitting or standing on the first day and vice versa on the second day. The current study was ethics approved by the UNITEC Research Ethics Committee (See Appendix A), and all participants gave written informed consent.

2.2 Participants

Thirty healthy volunteers were recruited by word-of-mouth or through an online participant recruitment service (researchstudies.co.nz). Eligibility for the study was established via a demographic questionnaire (see appendix eligibility questionnaire). The inclusion criteria were (a) between the ages of 18 and 50 years old; and (b) 14 female and 16 male participants. Exclusion criteria consisted of (a) musculoskeletal or other pathologies preventing or influencing their ability to stand for prolonged periods of time; (b) cognitive pathologies, such as chronic fatigue or any previous serious head injuries influencing their ability to perform cognitive tasks; (c) current usage of any medications which may affect concentration and cognitive performance; (d) a lack of fluency in written or verbal English (fluency was determined either by the researcher over the phone or during familiarisation if there were any doubts with the participants ability); (e) clinically diagnosed colour blindness; or (f) current usage of a standing desk.

2.3 Outcome Measures

Participants were subjected to a cognitive battery which included tasks from Perceptual Reasoning, Attention, Executive Function, Processing speed, and Working Memory domains. Block Design, Figure Weights and Matrix Reasoning were used to measure Perceptual Reasoning performance. These tasks were adapted from the Wechsler Adult Intelligence Scale IV (WAIS-IV; Wechsler, 2008) and also incorporated Raven’s Standard Progressive Matrices (SPM) within the Matrix Reasoning task to assess Perceptual Reasoning performance.

The WAIS-IV is a validated test of IQ and consists of four major areas: verbal comprehension, perceptual reasoning, working memory and processing speed. It was developed and tested using a normative sample of 2,200 adults and was stratified by age, sex, education level, ethnicity, and region to provide the highest reliability of results (Canivez & Watkins, 2010).

2.3.1 Block design

The Block Design task measured spatial perception, visual abstract processing and problem solving (Weschler, 1997). This task is usually considered to be a general intelligence test and has been shown to be highly correlated with IQ (Rozencwajg & Fenouillet, 2012). The Block Design task requires the participant to arrange a set of nine blocks (painted half red and half white) as they appear
in a printed pattern (see Figure 1). The task was measured by the number of seconds the participants took to correctly complete each item and was recorded in each participants' book (see Appendix I). Each set contained eight items for the participant to complete.

Figure 1. Example from the Block Design task.

2.3.2 Figure Weights

The Figure Weights task measures quantitative and analogical reasoning (Weschler, 1997). For the Figure Weights task the participant viewed a picture containing two or more scales (see Figure 2). Each item on the scales had its own individual weight. The balanced scales on the left (see Figure 2) displayed differing objects of varied quantity with equal weighting. In Figure 2 the weighting of three blue stars is equal to three red cups, while the scales to the right display one blue star and a “?” indicating a problem that requires solving. The participant is then required to select the most appropriate answer from the five boxes below to solve the equation, which, in the example below, would be Box 4 containing one red cup (see Figure 2). The answer given and the number of seconds it took the participant to respond were recorded. Participants were given 40 seconds per task item before the item was recorded as a non-response (Lichtenberger & Kaufman, 2013) and the next item presented (see Appendix J).
2.3.3 Matrix Reasoning (including the Raven’s Standard Progressive Matrices)

The Matrix Reasoning task measured non-verbal abstract problem solving, inductive reasoning and spatial reasoning (Weschler, 1997). We used two tasks amongst our testing of Matrix Reasoning performance, an adaptation of Matrix Reasoning tasks from the WAIS-IV and the Raven’s Standard Progressive Matrices (Raven, Raven, & Court, 1998). The order of tasks were dependant on the difficulty measured by mean average time taken during piloting.

The Raven’s Standard Progressive Matrices is one of the most widely used intelligence tests, shown to be less culturally biased than any other intelligence test (Brouwers, Van de Vijver, & Van Hemert, 2009), and also considered to be educationally unbiased (Mills, Ablard, & Brody, 1993). Raven’s SPM tests non-verbal reasoning ability and general intelligence (Van der Elst et al., 2013) predicting performance in a wide range of reasoning tasks (Prabhakaran, Smith, Desmond, Glover, & Gabrieli, 1997). Raven’s Standard Progressive Matrices has been used to test visual reasoning ability in other studies (Jaeggi et al., 2010; Ragni, Stahl, & Fangmeier, 2011). While Raven’s Standard Progressive Matrices is found to have a strong correlation to the Block Design sub-test of the WAIS-IV (Friedman et al., 2006), the Matrix Reasoning tasks in WAIS-IV are conceptually similar to Raven’s test (Groth-Marnat, 2009) and so have been included within our study.

Both Matrix Reasoning and Raven’s Standard Progressive Matrices tests required participants to observe a printed picture and choose the most appropriate response (from the choices numbered 1 - 5) that would fit into the missing box (see Figure 3). The number of correct answers and the number of seconds taken to complete each item were recorded (see Appendix K).
2.4 Procedure

Participants were required to attend a familiarisation session on a separate day prior to study commencement which ran for a one hour duration and was conducted by a research assistant. Familiarisation sessions included information about the study (see Appendix C), requirements of participants, and examples of all tasks. Once informed consent was obtained (see Appendix D), dates were arranged for both study days.

Participants maintained one posture, either standing or sitting, during all tasks throughout the study day. All study days were conducted in an office at the Unitec Institute of Technology, Mt Albert, Auckland, New Zealand. Each day commenced at 9:00am and finished at 4:30pm, and included two breaks (see Figure 4.). Participants could request a brief break at other times of the day between tasks if required, but these breaks were not recorded. There was a washout period of one to three weeks between interventions due to participant availability. Where possible, participants were tested on the same day of the week on each study day.

Participants completed three sets of cognitive tasks per day and each set consisted of 19 cognitive tasks and four work-related tasks. The three cognitive tasks used to assess Perceptual Reasoning performance were dispersed throughout the four other subtests belonging to the greater project of Attention, Processing Speed, Executive Function and Working Memory domains (see Appendix E). Data were collected by a research assistant who was the only other person in the testing room.

At the beginning of each study day, participants were asked to fill in a questionnaire detailing activities within the past 24-hours (see Appendix F). The questionnaire requested details of the participants’ exercise participation, current pain, tobacco use, alcohol / substance use, medication, sleep quality, fatigue levels, footwear and morning routine to compare variables considered to effect cognitive performance between study days. Where pain was noted, further clarification of the pain
was requested and in particular if pain was apparent on standing for prolonged periods then the participant was excluded.

Participants were asked to record their level of fatigue on a scale ranging from 0 (no fatigue or tiredness at all) to 10 (the worst fatigue or tiredness imaginable) at the end of each task set (see Appendix G). At the end of each study day, participants were asked to fill in a food diary detailing what they had consumed over the course of the day including drinks, food and supplements (see Appendix H) to encourage similarity between study days, as participants were asked to keep food intake and foot wear on the second study day as similar as possible to the first study day.

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:00-11:00am</td>
<td>Testing Session #1</td>
</tr>
<tr>
<td>11:00-12:00pm</td>
<td>(Early) Lunch Break</td>
</tr>
<tr>
<td>12:00-2:00pm</td>
<td>Testing Session #2</td>
</tr>
<tr>
<td>2:00-2:30pm</td>
<td>Afternoon Tea Break</td>
</tr>
<tr>
<td>2:30-4:30pm</td>
<td>Testing Session #3</td>
</tr>
</tbody>
</table>

*Figure 4. Testing schedule for study days*

2.5 Workstations

The room in which the study was conducted was furnished with a desk (sitting or standing), a chair, and a desktop computer used for completion of cognitive and work tasks. Workstation, monitor heights, temperature and lighting were adjusted to suit participant comfort in both conditions.

2.6 Statistical Analyses

Effects for all variables were analysed using multivariate two-way repeated-measures ANOVAs for each of the three tasks. Condition (sitting and standing) and Time of Day (Morning, Midday and Afternoon) were used as within-subjects factors.
Chapter 3: Results

During visual inspection of the data, one participant was identified as an extreme outlier in several of the task variables. The behaviour of this participant had also been noted by the researcher as being unusual and of concern. For this reason, the participant was excluded from all analyses.

3.1 Block Design

For the variable Block Design Average Time there was no main effect of Condition, $F(1,28) = 2.20, p = 0.149$, but there was a main effect of Time of Day, $F(2,56) = 24.65, p < 0.001$. Pairwise comparisons revealed there was a significant increase in speed between Morning ($M = 28.08, SE = 2.04$) and Midday ($M = 22.23, SE = 1.18$), $p < 0.001$, and between Morning and Afternoon ($M = 22.15, SE = 1.15$), $p < 0.001$, but no difference between Midday and Afternoon, $p > 0.99$. Additionally, there was no interaction between Condition and Time of Day, $F(2,56) = 0.65, p = 0.467$ (see Figure 5).

For the variable Block Design Correct there was no main effect of Condition, $F(1,28) = 0.69, p = 0.415$, nor was there a main effect of Time of Day, $F(2,56) = 0.32, p = 0.689$. There was no interaction between Condition and Time of Day, $F(2,56) = 2.69, p = 0.089$ (see Figure 6).

Figure 5. Average time of correct responses for the Block Design task, during Standing and Sitting conditions at three times of the day. Error bars represent standard error of the mean.
3.2 Figure Weights

For the variable Figure Weights Average Time there was no main effect of Condition, $F(1,28) = 0.26, p = 0.617$, or Time of Day, $F(2,56) = 0.68, p = 0.513$. There was no interaction between the two variables, $F(2,56) = 0.18, p = 0.838$ (see Figure 7).

The same analysis was run on the variable Figure Weights Correct. There was no main effect of Condition, $F(1,28) = 0.05, p = 0.946$, but there was a main effect of Time of Day, $F(2,56) = 10.12, p < 0.001$. Pairwise analyses for this variable showed that there was a significant increase in accuracy.
between Morning ($M = 4.90, SE = 0.23$) and Midday ($M = 5.66, SE = 0.25$), $p = 0.007$, and between Morning and Afternoon ($M = 5.85, SE = 0.18$), $p = 0.001$, but there was no difference between Midday and Afternoon, $p > 0.999$. There was no interaction between the two variables $F(2,56) = 0.05, p = 0.948$ (see Figure 8).

Figure 8. Mean number of correct responses for the Figure Weights task, during Standing and Sitting conditions at three times of the day. Error bars represent standard error of the mean.

3.3 Matrix Reasoning

For the variable Matrix Reasoning Average Time(s), there was no main effect of Condition, $F(1,28) = 0.81, p = 0.377$, but there was a main effect of Time of Day, $F(2,56) = 4.28, p = 0.019$. Pairwise analyses for this variable showed that there was a trend toward a significant increase in speed between Morning ($M = 10.50, SE = 0.54$) and Midday ($M = 9.58, SE = 0.43$), $p = 0.067$, and a significant decrease in speed between Midday and Afternoon ($M = 10.82, SE = 0.64$), $p = 0.015$, but there was no difference between Morning and Afternoon, $p > 0.999$. There was no interaction between the two variables $F(2,56) = 0.53, p = 0.925$ (see Figure 9).
Figure 9. Average time of correct responses for the Matrix Reasoning task, during Standing and Sitting conditions at three times of the day. Error bars represent standard error of the mean.

The same analysis was run on the variable Matrix Reasoning Correct. There was no main effect of Condition, $F(1,28) = 0.04$, $p = 0.952$, but there was a main effect of Time of Day, $F(2,56) = 3.17$, $p = 0.049$. Pairwise analyses for this variable showed a trend toward significance between Midday ($M = 6.64$, $SE = 0.16$) and Afternoon ($M = 6.22$, $SE = 0.20$), $p = 0.089$. There was no interaction between the two variables $F(2,56) = 0.64$, $p = 0.533$ (see Figure 10).

Figure 10. Mean number of correct responses for the Matrix Reasoning task, during Standing and Sitting conditions at three times of the day. Error bars represent standard error of the mean.
3.4 Fatigue

A repeated measures ANOVA was run on the variable Fatigue with Time of Day and Condition as within-subject variables. There was no main effect of Condition, $F(1,29) = 1.38, p = 0.25$, but there was a significant effect of Time of Day, $F(2,58) = 20.20, p < 0.001$.

For Time of Day there was a significant difference between Morning ($M = 3.58, SE = 0.27$) and Midday ($M = 4.48, SE = 0.25$), $p = 0.003$, between Morning and Afternoon ($M = 5.38, SE = 0.29$), $p < 0.001$, and between Midday and Afternoon, $p = 0.003$. There was no interaction between Condition and Time of Day, $F(2,58) = 1.83, p = 0.173$ (see Figure 11).

Figure 11. Mean self-rated level of fatigue post-test after Standing and Sitting conditions at three times of day. Error bars represent standard error of the mean.
Chapter 4: Discussion

The primary objective of the current study was to investigate the effect of standing versus sitting on Perceptual Reasoning performance. The results showed no significant differences in performance between sitting and standing conditions in any of the three Perceptual Reasoning tasks for either accuracy or speed. This implies that, in this sample, there was no benefit in standing in terms of Perceptual Reasoning. Although importantly, the results also show there is neither any detriment to standing whilst working. The findings can, therefore, support the encouragement of standing to work whenever possible and appropriate due solely to the health benefits already addressed in the literature (de Rezende et al., 2014; Proper et al., 2011; World Health Organisation / World Economic Forum, 2008).

While there were no significant findings between sitting and standing conditions, there were significant differences between the sessions for Time of Day, revealing mixed results across the three tasks, and these varied also between the speed and accuracy measures. Performance across the day improved significantly in the speed of Block Design performance and in the accuracy of Figure Weights performance. Performance across the day for the Matrix Reasoning task, however, was variable, whereby there was a significant increase in speed at Midday that then returned to Morning levels in the Afternoon session, and there was a weak reduction in accuracy in the Afternoon for this task.

It is beyond the scope of this thesis to incorporate the wider project results (see Appendix L), but it is worth noting here that, in general, performance in most other tasks improved throughout the day. This may have been due to a practice effect but was in contrast to the findings from the Fatigue data (that has been presented here). Participants scored their perception of fatigue on a scale from 0 to 10 (where 10 was “the worst fatigue or tiredness imaginable”) and results showed a condition-irrelevant and significant increase in perceived fatigue between all three sessions of the testing days. It would follow, then, that we might expect to see a decrease in task performance across the day due to tiredness, or at least a cancelling effect between practice and fatigue, whereby performance would be constant across the day. Interestingly, unlike other cognitive domains tested in the wider project, the results of the Perceptual Reasoning tasks presented here are most in line with the latter prediction. On the whole, whether regarding task speed or task accuracy, performance was generally constant across the day. It is speculated that the more difficult, intellectual, problem-solving nature of these tasks may be the reason why fatigue seems to have had a more profound effect on performance than in other domains.

Fluid Reasoning is one of the abilities tested in Perceptual Reasoning tasks. Working Memory and Fluid Reasoning performance have been reportedly difficult to differentiate (Chuderski, 2013, 2015; Martinez et al., 2011). Bantoft et al. (2015) and Russell et al. (2015) have reported no
significant difference between standing and sitting conditions in Working Memory performance. The similar findings between this study and that of Bantoft et al.'s (2015) may be due to utilization of similar neural networks in Working Memory and Fluid Reasoning (Barbey, Colom, Paul, & Grafman, 2014) or may have been due to the methodological similarities between studies such as using participant specific workstation heights, a seven day washout period, and testing occurred at the same time of each study day. The 7.5 hour duration of the current study exceeded Bantoft et al.'s (2015) 60 minute duration and yet, no performance difference was found between standing and sitting. Time of Day performance fluctuations found within-subjects indicate the necessity of measuring effects over a whole day. While the current study tested Morning, Midday and Afternoon performance, other studies (Bantoft et al., 2015; Russell et al., 2015; Schraefel et al., 2012) tested at one time of day limiting the transferability of results to an average working day.

Fatigue was shown to increase generally throughout each study day. Negative performance effects of mental fatigue on executive function tasks (van der Linden et al., 2003) and arm motor control (Rozand et al., 2015) imply that performance decrements may be expected during the Afternoon session in the current study. As afternoon performance decrements occurred in both Matrix Reasoning variables it is possible that the cognitive complexity of Matrix Reasoning tasks exceeded the complexity of Block Design and Figure Weights (Van der Linden, Frese, & Meijman, 2003).

The strengths of the current study are based on the transferability of findings to office environs. The duration of 7.5 hours simulated a typified working day, whereas previous studies have measured a maximum duration of 1 hour (Bantoft et al., 2015; Russell et al., 2015; Schraefel et al., 2012). Furthermore, the sample age range of 18 – 50 years old was considered a comparable age range to typical full-time working populations and was restricted in order to reduce the potential for additional performance variations associated with older age brackets (Salthouse, 2006).

4.1 Limitations

Prolonged workplace standing has been shown to increase musculoskeletal discomfort and pain (Drury et al., 2008; Nelson-Wong et al., 2010; Waters & Dick, 2015), and pain is reported to negatively influence work performance (Lindegård, Larsman, Hadzibajramovic, & Ahlborg, 2013). By alternating sitting and standing postures, these musculoskeletal issues may be diminished. Furthermore, sit-stand interventions are considered to be more effective than static standing interventions for increasing energy expenditure (Júdice et al., 2015), decreasing musculoskeletal pains and reducing muscle fatigue (Balasubramanian, Adalarasu, & Regulapati, 2009; Callaghan & McGill, 2001). As the current study used a standing only desk, the results are not necessarily transferable to sit-stand desks.

Fatigue was measured in the current study by a visual analogue scale (see Appendix G) which may have not been sufficient to detect work related fatigue sufficiently due to the reliance on self-reporting. Furthermore, the wording of the visual analogue scale was generalised and so it is
unclear whether participants were reporting mental fatigue and/or physical fatigue. Feedback on mental and physical fatigue as separate and specific entities would help determine the type of fatigue that may have influenced results. Recent studies have identified that multiple measures of fatigue, including objective and subjective measures, may represent fatigue levels more reliably (Völker, Kirchner, & Bock, 2015, 2016). Furthermore, as participants were unable to be blinded to the condition, reporting bias may have influenced perceived fatigue levels that may have been identified by recording objective measures of fatigue.

The tasks used in the current study were adaptations from the WAIS-IV Perceptual Reasoning Index and Raven’s Standard Progressive Matrices. These adaptations were used in order to produce six sets of similar difficulty, as matched sets of these tasks are not currently available in the original measures. During piloting for each task in the Perceptual Reasoning domain, every example in each set was timed to gauge the complexity of each example. These examples were then ordered from fastest average time to slowest average time and then placed into three sets. The three sets were then duplicated and elements of each example altered to create three more matched sets that were administered on Day 2 in an attempt to decrease a practice effect. While efforts were made to replicate the same difficulty in each set, there is no certainty that the complexity was uniform among all sets. As these tasks were direct adaptations initially, the validity and reliability of these tasks warrant comparison with the standardised measures in future research.

4.2 Information for Stakeholders

The World Health Organisation recommends globally decreasing sedentary behaviour in the workplace in an attempt to decrease the prevalence of non-communicable diseases (World Health Organisation / World Economic Forum, 2008). Furthermore, reducing sedentary behaviour in the workplace assists the World Health Organisation (2013) goal to achieve a 10% decrease in non-communicable diseases by the year 2025. While the prospect of supporting a global health movement without detriment to work performance may appeal to some businesses, the prospect of future work performance increases may widen the appeal. The findings in the current study illustrate baseline effects of using a standing desk on Perceptual Reasoning performance within an office setting. Long term work performance increases and initial performance decrements found in previous active workstations studies (Ben-Ner et al., 2014; Koepp et al., 2013) indicate that work related performance may improve in 12 months. As the findings in the current study indicate no performance effect between standing and sitting conditions without an acclimatization period, future longitudinal studies are needed to determine the long term effects of standing workstations on Perceptual Reasoning performance.

The results from the current study are intended to inform prospective end users, human resource departments and researchers in workplace health and cognitive neuroscience fields about the short-term effects of standing workstations on Perceptual Reasoning performance. While the pain associated with prolonged standing only workstations decreases the likelihood of widespread implementation, sit-stand workstations may be a valid solution. Dynamic movement has been
reported by Callaghan & McGill (2001) as more beneficial for health than static postures. The
difficulties in assimilating dynamic movement into a traditionally static workplace in the form of active
workstations has proven to be a difficult balancing act between work-related performance and health
benefits. Sit-stand conditions have demonstrated similar cognitive performance effects to sitting
(Bantoft et al., 2015; Russell et al., 2015), and increased energy expenditure relative to static standing
(Júdice et al., 2015). According to a Cochrane review, sit-stand workstations are the only active
workstation shown to reduce sitting time (Shrestha et al., 2016). Sit-stand workstations offer
increased feasibility, work performance, and the lowest intervention cost out of current active
workstations.

While the current study has shown the effects of a standing only workstation on Perceptual
Reasoning, there is a need for future research to determine the effect that sit-stand workstations have
on Perceptual Reasoning performance. Furthermore, the limitations of the current study guide
recommendations for future research consisting of (a) increasing the length of the study to one month
or more to enable participants more time to adapt to a foreign work environment as improved work-
related performance has been demonstrated in previous studies with increased study length (Ben-Ner
et al., 2014; Koepp et al., 2013), (b) using a sit-stand intervention instead of a standing desk for
increased health benefits (Callaghan & McGill, 2001; Júdice et al., 2015) and (c) including multiple
measures of fatigue, including objective and subjective measures, in order to enhance the specificity,
reliability and accuracy of fatigue levels (Völker et al., 2015, 2016) in relation to cognitive
performance. Future studies that incorporate these suggestions will likely improve the knowledge
base of sit-stand workstations and may provide evidence in support of future widespread
implementation that would subsequently help reduce global sedentary behaviour.

4.3 Conclusion

Standing and sitting produce similar Perceptual Reasoning performance when administered
among an experimental cognitive test battery over the duration of 7.5 hours in healthy 18 – 50 year
old participants. This finding has important implications for global workplace healthcare and identifies
standing interventions as a potential solution to reducing sedentary behaviour in workplaces from
schools to offices without work related performance detriment.

References

Aarts, H., & Dijksterhuis, A. (2000a). Habits as knowledge structures: automaticity in goal-directed

of travel habit. *Journal of Environmental Psychology, 20*(1), 75–82.
http://doi.org/10.1006/jevp.1999.0156


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Kesler, S. R., Haberecht, M. F., Menon, V., Warsofsky, I. S., Dyer-Friedman, J., Neely, E. K., & Reiss,


Association for the Study of Obesity, 13(10), 835–47. http://doi.org/10.1111/j.1467-789X.2012.01012.x


Appendix A: Ethics Approval Letter

Jamie Mannion and Lucy Patson
Osteopathy
Building 52
Unitec Mt Albert Campus
Auckland

25.9.14

Dear Jamie and Lucy,

Your file number for this application: **2014-1085**
Title: **To what extent does working from a standing desk influence cognitive performance.**

Your application for ethics approval has been reviewed by the Unitec Research Ethics Committee (UREC) and has been approved for the following period:

**Start date: 25.9.14**
**Finish date: 25.9.17**

Please note that:

1. The above dates must be referred to on the information AND consent forms given to all participants.
2. You must inform UREC, in advance, of any ethically-relevant deviation in the project. This may require additional approval.

You may now commence your research according to the protocols approved by UREC.
We wish you every success with your project.

Yours sincerely,

Sara Donaghey
Acting Deputy Chair, UREC
Appendix B: Participant Demographic Questionnaire

Participant Eligibility and Demographic Questionnaire

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?  □ Yes □ No

(on one day of the study you will be required to stand for long periods of time – 1.5 hours)

Do you have, or have you had, any of the following:

a. Serious head injuries (including concussions)  □ Yes □ No

b. Other issues affecting your ability to concentrate?  □ Yes □ No

c. Medication affecting your ability to concentrate?  □ Yes □ No

(many of the tasks involved in the study require sustained concentration)

Are you clinically colour-blind?  □ Yes □ No

(some of the tasks involve discriminating between different colours – e.g., red, blue, green)

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:
First Name: ___________________________ Gender: ___________________________
Surname: ___________________________ Date of Birth: __________________________
Height: _______ Weight: _______ Ethnicity: ___________________________
Home phone: ________________________ Work phone: ________________________
Email Address: ___________________________________________________________
Postal Address: __________________________________________________________________

Do you speak any other languages apart from English? □ Yes □ No
If yes, please specify:

What is your usual occupation?

What (if any) regular physical activity do you maintain (include any sports you play)?

What (if any) are your other hobbies (e.g., music, computer games, puzzles, reading)?

How would you describe the level of physical activity at your work:

□ Sedentary (brief standing and walking required)
□ Light (frequent standing and walking required)
□ Moderate (required to lift small loads / some bending, or frequent walking)
□ Heavy (frequent lifting required, often over 10 kgs, or lots of walking)
□ Very heavy (consistent lifting, often over 20 kgs, or frequent running)

Do you currently use a standing desk? □ Yes □ No

How many hours would you spend sitting in an average day at work?

How many hours would you spend sitting in an average day at home?
Have you sustained any injuries which affect your ability to work? □ Yes □ No

Please provide details:

Do you experience pain on a regular or sustained basis? □ Yes □ No

Please provide details (including intensity of pain):

What academic qualifications do you hold and/or are currently studying toward? Include school qualifications.

Have you participated in any cognitive testing before? □ Yes □ No

Please provide details:
Appendix C: Study Information for participants

Research Project Title:

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

Synopsis of project

Recent evidence shows that a high level of sedentary behaviour, 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 enrol.

If you choose to enrol, 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:

Lucy Patston
021980509
(09)8154321#8475
lpatston@unitec.ac.nz

Jamie Mannion
021673832
(09)8154321#8475
jmannion@unitec.ac.nz

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 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 E: Ordered List of Cognitive Tasks

<table>
<thead>
<tr>
<th>Task</th>
<th>Cognitive domain tested</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Trail making</td>
<td>Executive Function</td>
</tr>
<tr>
<td>2. Symbol search</td>
<td>Processing speed</td>
</tr>
<tr>
<td>3. Continuous performance task – 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</td>
<td>Executive Function</td>
</tr>
<tr>
<td>7. Cancellation</td>
<td>Processing speed</td>
</tr>
<tr>
<td>8. Figural intersection</td>
<td>Attention</td>
</tr>
<tr>
<td>9. Letter number sequencing</td>
<td>Working Memory</td>
</tr>
<tr>
<td>10. Visuospatial search</td>
<td>Executive Function</td>
</tr>
<tr>
<td>11. Rapid picture naming</td>
<td>Processing speed</td>
</tr>
<tr>
<td>12. Continuous performance task - 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>Executive Function</td>
</tr>
<tr>
<td>16. Coding</td>
<td>Processing speed</td>
</tr>
<tr>
<td>17. Paced auditory serial addition test</td>
<td>Attention</td>
</tr>
<tr>
<td>18. Block design</td>
<td>Perceptual Reasoning</td>
</tr>
<tr>
<td>19. Visual reproduction</td>
<td>Working Memory</td>
</tr>
</tbody>
</table>
Appendix F: Participant log for assessment of similarities between study days

Set 1 – 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?
   □ no drinks
   □ 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?

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>Excellent</td>
</tr>
</tbody>
</table>

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 G: Level of Fatigue Scale

Level of Fatigue Scale

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

<p>| | | | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
</tbody>
</table>
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)

<table>
<thead>
<tr>
<th>Time</th>
<th>Food</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breakfast</td>
<td></td>
</tr>
<tr>
<td>Morning Tea</td>
<td></td>
</tr>
<tr>
<td>Lunch</td>
<td></td>
</tr>
<tr>
<td>Afternoon Tea</td>
<td></td>
</tr>
</tbody>
</table>

3. Provide a list of any supplements consumed today (Example: Multivitamin, fish oil, protein powder. If Nil, please state)
Appendix I: Example of marking sheet for the Block Design task

Standing Desk Study 2014/2015  Participant ID: ___________ Day1/2  seated/standing

Set 1 – Task 18: Block Design

Instructions to Participants:

In this task you will be given nine blocks to recreate a design. All the blocks are exactly the same. They each have two red sides [point to both sides], two white sides [point to both white sides], and two sides that are half red and half white [point to these sides]. Have a look at these now.

You will be shown a design similar to this one [point to example]. Using the blocks you have, recreate this design and then tell me when you have finished.

Whilst this task is timed, it is important that you recreate the design as accurately as possible and the right way up.

Try this one [point to example];
[Correct any errors the participant makes and ensure the design is the right way up.]

Do you have any questions? [answer any questions].
Ok, are you ready? Here’s the first design.

For research use only:

<table>
<thead>
<tr>
<th>Item</th>
<th>Seconds to complete</th>
<th>✓ or ✗</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Item 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Item 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Item 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Item 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Item 6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix J: Example of marking sheet for the Figure Weights task

Standing Desk Study 2014/2015          Participant ID: __________ Day 1/2  Seated/Standing

Set 1 – Task 5: Figure Weights

Instructions to Participants:

For this task you will be shown an image of a set of scales and your job is to balance the scales by selecting the correct answer below. Work as quickly and accurately as possible. You have 40 seconds to complete each item.

Here is an example [show example in resource book and ask participant to solve].

Do you have any questions? [Answer any questions]

Ok, are you ready? Here’s the first puzzle.

For research use only:

Examinee has up to 40 seconds to complete each task, if not, move on to the next task stating “let’s try another one” and record “40+” in the [Seconds to complete] box and an ‘X’ in the [✓ or ✗] box.

<table>
<thead>
<tr>
<th>Item</th>
<th>Correct answer</th>
<th>Seconds to complete</th>
<th>Participant’s answer</th>
<th>✓ or ✗</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item 1</td>
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<td>0</td>
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<td>Item 2</td>
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<td>Item 4</td>
<td>4</td>
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<td></td>
<td></td>
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<tr>
<td>Item 5</td>
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<td>Item 6</td>
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<tr>
<td>Item 7</td>
<td>2</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix K: Example of marking sheet for the Matrix Reasoning task

Standing Desk Study 2014/2015  Participant ID: _________ Day 1/2  Seated/Standing

Set 1 – Task 14: Matrix Reasoning

Instructions to Participants:

For this task you will be shown a puzzle with a series of images that are related in some way. One of these images has been replaced by a question mark.

In order to complete the series, choose the most appropriate image that you think would replace the question mark from one of the numbered boxes at the bottom of the page.

You have 40 seconds to complete each item.

Here is an example: [Show example in resource book]

Do you have any questions? [Answer questions]

Ok, are you ready? Here’s the first puzzle.

For research use only:

If the task is not completed within 40 seconds then move on to the next task stating “let’s try another one” and mark “40+” in the [Seconds to complete] box and “X” in the [✓ or ✗] box.

<table>
<thead>
<tr>
<th>Item</th>
<th>Correct answer</th>
<th>Seconds to complete</th>
<th>Participant’s answer</th>
<th>✓ or ✗</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item 1</td>
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<td></td>
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<td>Item 2</td>
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<td>Item 7</td>
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<td>Item 8</td>
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## Appendix L: General Results of Full Standing Desk Study

<table>
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<tr>
<th>Task 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>
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<tr>
<td>Cancellation</td>
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<td>.375</td>
<td>.008</td>
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<td>Coding</td>
<td>Number Correct</td>
<td>.091</td>
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<tr>
<td>Rapid Picture</td>
<td>Total Time to Complete (s)</td>
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<td>.055</td>
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<tr>
<td>Naming</td>
<td>Number Correct</td>
<td>.922</td>
<td>&lt; .001</td>
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<td>Symbol Search</td>
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<td>.210</td>
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<td><strong>Domain: Attention</strong></td>
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<td>CPT-AX</td>
<td>Average RT</td>
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<td>.000</td>
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<td>CPT-Inhibition</td>
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<td>Number Correct</td>
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<td>Figural Intersection</td>
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<td>PASAT</td>
<td>Number Attempted</td>
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<td>Number Correct</td>
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<td><strong>Domain: Working Memory</strong></td>
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<td></td>
</tr>
<tr>
<td>Arithmetic</td>
<td>Percentage Correct</td>
<td>.568</td>
<td>.060</td>
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<td></td>
<td>Percentage Correct</td>
<td>.135</td>
<td>.017</td>
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<td>Letter-number</td>
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<td>Sequencing</td>
<td>Percentage Correct</td>
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<td>&lt; .001</td>
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<td>Spatial Span</td>
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<td></td>
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<tr>
<td>Visual Reproduction</td>
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<td><strong>Stroop Effect</strong></td>
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<td>Colour Naming</td>
<td>.634</td>
<td>.015</td>
<td>.105</td>
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<td>Interference</td>
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<td><strong>Trail Making</strong></td>
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<tr>
<td>Average Time to Complete</td>
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<td>&lt; .001</td>
<td>.646</td>
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<td><strong>Verbal Fluency</strong></td>
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<td></td>
</tr>
<tr>
<td>Number Correct</td>
<td>.945</td>
<td>&lt; .001</td>
<td>.706</td>
</tr>
</tbody>
</table>

1

2
Use of thesis/dissertation/research project

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Full title of thesis/dissertation/research project:

WHAT ARE THE EFFECTS OF SITTING VERSUS STANDING ON PERCEPTUAL REASONING THROUGHOUT A SIMULATED WORKING DAY?

Department of OSTEOPATHY

Degree: MAJOR OF OSTEOPATHY Year of presentation

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