Effects of standing workstations on occupational sedentary behaviour and metabolic health in office workers: A single-case study design

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A thesis submitted in partial fulfilment of the requirement for the degree of Master of Osteopathy

Unitec Institute of Technology, 2015
Declaration

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This thesis entitled Effects of standing workstations on occupational sedentary behaviour and metabolic health in office workers: A single case study design is submitted in partial fulfilment of the requirements for the degree of Master of Osteopathy

Candidates Declaration

I confirm that:

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

Research Ethics Committee Approval Number: 2013-1029

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Date: 14th April 2015

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### Abbreviations

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<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>BMI</td>
<td>Body mass index. A calculation of an individual's mass based on their height and weight</td>
</tr>
<tr>
<td>CVD</td>
<td>Cardiovascular disease</td>
</tr>
<tr>
<td>kCal</td>
<td>Kilocalorie. Unit of energy expenditure equal to 1000 calories. One calorie is the amount of energy required to heat 1 gram of water by 1 °C</td>
</tr>
<tr>
<td>MetS</td>
<td>Metabolic syndrome</td>
</tr>
<tr>
<td>T2DM</td>
<td>Type 2 diabetes mellitus</td>
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</table>
Abstract

Introduction: Metabolic Syndrome is a collection of clinical signs that represent unfavourable metabolic changes in the body. Metabolic syndrome has been associated with increasing risk of cardiovascular disease, Type II diabetes mellitus, stroke, and all-cause mortality. In recent years sedentary behaviour has been linked to markers of metabolic syndrome, cardiovascular disease and all-cause mortality. Research shows that the negative effects of sedentary behaviour are separate from the benefits of physical activity and that steps should be taken to mitigate harm by replacing sedentary behaviour with regular light intensity physical activity. For example, substituting sitting for standing.

Methods: This single-case design study investigated the effects of a sit-stand or standing workstation on physical activity and metabolic markers: central obesity, blood pressure, blood glucose, triglycerides and HDL cholesterol. Six occupationally sedentary participants aged between 25 and 40 years with a BMI between 25 and 30 kg/m² were recruited from the Auckland population. During a 5 week baseline period, a 3 week ‘phase-in’ period and a 13 week intervention period, participants were assessed every 4 weeks using anthropometric and biochemical measurements in order to analyse any changes to the markers of metabolic syndrome. Inclinometry recorded during working hours was used to analyse changes to daily occupational sitting and standing duration.

Results: Changes occurred for daily sitting and standing time for 5 participants. Standing time increased following the introduction of the standing workstation; the smallest increase was 111 min/day and the largest increase was 341 min/day. The smallest decrease in daily sitting time was 107 minutes and the largest decrease was 311 min/day. During the intervention period, the changes to daily sitting and daily standing times remained stable. Three participants showed decreases in waist circumference of between 2.5 and 6.7 cm. Meaningful changes in other metabolic markers were only seen in a single increase of blood glucose, and a single decrease of blood triglycerides.

Conclusion: The use of sit-stand or standing workstations reduced daily occupational sitting and increased daily occupational standing in all participants, where inclinometry data were available. These changes were stable across the entire intervention period suggesting high acceptability of the standing workstation. The failure to detect changes to metabolic markers may be suggestive of study limitations, such as duration, or the complexity of metabolic syndrome. Future studies may use randomising and control groups with a larger sample.
Chapter 1. Metabolic syndrome and sedentary behaviour
1.1. Background and aims of this study

Steady increases in levels of sedentary behaviour in the last 50 years, with decreases in physical activity, have led to recognition of three major domains of sitting: transport, work, and leisure time (Brownson, Boehmer, & Luke, 2004; Juneau & Potvin, 2010). As a form of sedentary behaviour, sitting is more prevalent in young adults and in those with higher levels of education (Bauman et al., 2011). With a push in Western cultures for tertiary education and an economic climate demanding growth, ‘white-collar’ employment such as that found in professional or administrative roles may result in employees experiencing many hours of occupational sitting per day. In New Zealand, 50% of the population spend at least 4 hours a day in a sedentary state (Bauman et al., 2011). When compared to those who sit <2 h/day, those who sit for >4 h/day show increased risks for CVD, T2DM and all-cause mortality (Dunstan et al., 2010). The amount of time spent in occupational sedentary behaviour is not known for New Zealand. Drawing from Australian data (Mummery, Schofield, Steele, Eakin, & Brown, 2005), it is possible that 30% of New Zealand adults in full-time occupation spend at least 3.5 hours per day sitting down. In addition, for the 440,000 commuters in the greater Auckland metropolitan area, commuting may total between 40 and 80 minutes per day of driving or on public transport (Statistics New Zealand, 2013). Combine commuting and occupational sitting, with any sedentary time outside of work and it is easy to see that daily sitting time may be high for New Zealand working adults.

Metabolic syndrome (MetS) is a collection of unfavourable clinical signs that occur commonly together as a cluster. Although there is some dispute as to its classification, MetS is primarily comprised of central obesity, insulin resistance, dyslipidaemia and hypertension (Alberti et al., 2009; Alberti, Zimmet, & Shaw, 2006; The National Cholesterol Education Program, 2001). The development of MetS in individuals is a strong predictor for stroke, cardiovascular disease (CVD), Type II diabetes (T2DM) and all-cause mortality (Isomaa et al., 2001; Mottillo et al., 2010). The specific prevalence of MetS is not known for the entire New Zealand population; however, considering a third of the population are classified as being obese and 1 in 10 are currently receiving pharmaceutical treatment for hypertension or hypercholesterolaemia, it is possible that the prevalence in New Zealand might be within the range of 15-25% of the adult population. However, as the actual prevalence is unknown, objective research is required to further examine the impact of MetS.

Recent data shows that long periods of sedentary behaviour, such as prolonged sitting, are correlated with unhealthy changes to the markers of MetS including raised BMI (Mummery et al., 2005), raised waist circumference, high blood pressure, decreased HDL cholesterol (Wijndaele et al., 2009), increased blood glucose (Healy et al., 2007) and increased risks of developing MetS (Bertrais
et al., 2005). Sedentary time has also been implicated in elevated risk of cardiovascular events and all-cause mortality (Stamatakis, Hamer, & Dunstan, 2011). Moreover, it appears that the comparatively short periods of leisure time physical activity do not mitigate the detrimental effects of longer daily periods of sedentary behaviour (Healy, Matthews, Dunstan, Winkler, & Owen, 2011; Stamatakis, Hamer, & Dunstan, 2011; Wijndaele et al., 2009).

Long periods of daily sitting, as that occurring in occupations such as professional, administrative or clerical office work, may be harmful to health. Recommendations to meet 150 minutes a week of moderate level activity (Haskell et al., 2007) may be ineffective in reversing the detrimental changes seen as a result of prolonged sedentary behaviour and there have been calls for a new focus to be placed on reducing daily sedentary time (Dunstan, Howard, Healy, & Owen, 2012). To date, there have been few intervention programmes aimed at specifically reducing levels of occupational sitting (Chau et al., 2010), but with further evidence emerging about the harm caused by prolonged sedentary behaviour, there is a pressing need to investigate ways to reduce the long term effects on the health of the population. The majority of attempts to reduce sitting time exist in the domain of leisure-time physical activity and any interventions intended to reduce occupational sitting are limited in number.

This study is a preliminary investigation into the use of a standing workstation to reduce occupational sedentary behaviour. Through the measurement of waist circumference, BMI, systolic and diastolic blood pressure, blood glucose, triglycerides and HDL cholesterol, data were used to explore relationships between the use of a standing workstation and potential changes in markers of MetS. Additionally, by using inclinometry to objectively record standing and sitting duration, changes to daily occupational standing and sitting times were identified.

1.2. Format of this thesis

This work is presented in a chapter based thesis format. Chapter 1 provides background information on MetS and the effects of prolonged sedentary behaviour on the markers of metabolic health. Chapter 2 is a literature review examining the effects and acceptability of sit-stand and standing workstations on metabolic health. Chapter 3 describes study methods, design, data collection and analysis. Chapter 4 presents the results for each participant. Chapter 5 concludes with a discussion examining the results of the study, and includes limitations and recommendations for future research.
1.3. Rationale for study design

There is a distinct lack of research on occupationally driven sedentary behaviour patterns in the workplace. There is also very limited research on interventions to reduce occupational sedentary behaviour in predominantly sitting-based workplaces, as experienced by professional or administrative workers. While strong evidence indicates that excess sitting is associated with a range of negative health effects (Dunstan et al., 2010; Matthews et al., 2012; Stamatakis et al., 2011; Van Gaal, Mertens, & De Block, 2006), well controlled clinical trial data is required to test an occupational intervention on sitting on a large scale. The most appropriate research design to investigate causal relationships between the use of standing workstations and changes in MetS markers would be a randomised controlled clinical trial. Designs of this type require the sample to be randomised to an intervention or control group, where participants are blinded to the application of intervention or placebo (Akobeng, 2005). While a study of this nature would provide greater robustness of data with reduced bias, there is little current scientific evidence of this novel intervention to justify the resource requirements, high financial and time costs associated with the design and execution of a randomised controlled trial to investigate standing workstations and health effects. By using a single-case design study, indications about the relationships may be identified that enable better quality hypothesis generation for subsequent clinical trial investigations.

The use of single-case design studies allows for researchers to experiment with novel interventions to gain insight into possible relationships between the intervention and dependent variables, by using an N-of-1 design where the same outcome variables are repeatedly measured through a number of phases (Kratochwill et al., 2010; Logan, Hickman, Harris, & Heriza, 2008). Participants act as their own control through a baseline phase before introduction of the intervention and in many cases a withdrawal phase is included.

Interpretation of single-case design studies is performed through visual analysis, focusing on clinical significance rather than statistical significance (Gross, 2008; Kratochwill et al., 2010). Each participant’s results are presented individually with phase trend, variability and level within and across phases, so that the interpreter of the single-case study can generate sound hypotheses about the relationship between intervention and dependent variables.
1.4. Metabolic syndrome

1.4.1. Definition

Metabolic Syndrome is a cluster of clinical signs that appear to occur more commonly together than might be expected by chance. The identification of the components is attributed to Reaven (1988) when he identified a group of systemic changes associated with increased risk of CVD; namely hypertension, impaired glucose tolerance, hyperinsulinaemia, increased plasma triglycerides and decreased (HDL cholesterol). Although Reaven (2006) is a harsh critic of the concept of MetS, his work has become the corner-stone for the definition of MetS. The collection of these metabolic markers has been strongly implicated in the development of CVD and the development of T2DM in non-diabetic individuals (Alberti et al., 2006; Grundy, Brewer, Cleeman, Smith, & Lenfant, 2004; Roger et al., 2011).

The classification of MetS has been debated in recent years, with particular attention paid to whether it is insulin resistance or obesity that best explains the increased risk. Several classifications have been defined and even though many are now dated, they are still regularly used. The World Health Organisation criteria (referred to as WHO criteria) (1999), National Cholesterol Education Program—Third Adult Treatment Panel criteria (referred to as ATPIII criteria) (2001) and the European Group for the Study of Insulin Resistance criteria (referred to as EGIR criteria) (Balkau & Charles, 1999) have each released their own definitions of MetS along with criticisms of the criteria used by other groups. Whilst each group agrees that a collection of clinical signs is present, which predisposes people to CVD and T2DM, they place different emphasis on the relevance, importance and specific cut-off levels for the markers known under the current understanding of MetS; insulin resistance, dyslipidaemia, central obesity and hypertension. At the heart of the argument is the fact that MetS is still poorly understood and that finding the balance between an accurate definition using epidemiological studies and a description that translates into easily administered office-based tests, is difficult. The euglycaemic clamp technique used in the WHO criteria, for example, is the ‘gold-standard’ for assessing insulin resistance and requires maintained glucose infusion for a minimum of 120 minutes with blood samples taken every 10 minutes (Kim, 2009). While this method is very accurate, it is highly impractical for wide-scale epidemiological studies or clinical settings, where a simple tool is needed to aid in diagnosis and treatment (Eckel, Grundy, & Zimmet, 2005).

In 2006, the International Diabetes Federation (International Diabetes Federation, 2006) held a consensus workshop (Alberti et al., 2006) in order to produce a new definition of MetS and standardise the measurement for clinical practice and to improve the methodological quality of
international epidemiological studies. More recently, a joint interim statement has been released by the International Diabetes Federation, World Health Organisation, The National Heart, Blood and Lung Institute, American Heart Association and the International Association for the Study of Obesity (Alberti et al., 2009) in order to move closer to a unified definition for diagnosis (Table 1.4.1). Importantly, each of these criteria for diagnosis represents a ‘crude’ measurement for a complicated spectrum of an inability to maintain homeostasis. For example, a component of MetS diagnosis is based on a combination of high triglycerides and low levels of HDL cholesterol; however, this is only one small component of a spectrum of changes. The impact of insulin resistance and central obesity also produces changes in unmeasured markers such as a proliferation of triglyceride rich LDL cholesterol, as well as a decrease in LDL size which significantly increases risk of CVD (Reaven, 2006). These changes are important but also make for a more complicated diagnosis. Instead, MetS uses selected signposts to represent a large, complicated systemic change. Finally, the diagnostic criteria for MetS will constantly evolve as we understand more about the metabolic changes in the body. As new tools are developed to diagnose and understand the impact of the ‘cardiometabolic risk’ (Després & Lemieux, 2006), MetS may no longer be defined as a simple grouping of commonly occurring clinical signs.

Table 1.4.1 – The Metabolic Syndrome Joint Interim Statement. Table adapted from (Alberti et al., 2009)

<table>
<thead>
<tr>
<th>Metabolic Syndrome</th>
<th>is diagnosed as the presence of any three of the following:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central obesity</td>
<td>Elevated waist circumference (country specific)</td>
</tr>
<tr>
<td>Raised triglycerides</td>
<td>≥1.7 mmol/l (150 mg/dl) or Specific treatment for this lipid abnormality</td>
</tr>
<tr>
<td>Reduced HDL cholesterol</td>
<td>&lt; 1.0 mmol/l (40 mg/dl) in males or &lt; 1.3 mmol/l (50 mg/dl) in females or Specific treatment for this lipid abnormality</td>
</tr>
<tr>
<td>Raised blood pressure</td>
<td>Systolic: ≥130 mmHg and/or Diastolic: ≥85 mmHg or Specific treatment of previously diagnosed hypertension</td>
</tr>
<tr>
<td>Raised fasting glucose</td>
<td>Fasting plasma glucose ≥5.6 mmol/l (100 mg/dl) or Specific treatment for elevated glucose</td>
</tr>
</tbody>
</table>
1.4.2. Clinical outcomes and burden of disease

The presence of MetS increases the risks of developing CVD, T2DM and stroke, as well as an increased risk of all-cause mortality (Isomaa et al., 2001; Mottillo et al., 2010). A limitation inherent in quantifying risk lies in the multiple definitions of MetS. Nonetheless, there is strong evidence to show that those with MetS have increased risk of developing CVD (ATPIII random effects estimate = 1.65, 95% CI = 1.38-1.99, WHO fixed effects estimate = 1.37, 95% CI = 1.09-1.74) and an increased risk for all-cause mortality (ATPIII random effects estimate = 1.27, 95% CI = 0.98 – 1.5, WHO fixed effects estimate = 1.93, 95% CI = 1.39-2.67) when compared to those without MetS (E. Ford, 2005).

Cardiovascular disease accounted for an estimated 17.5 million deaths worldwide in 2012; 31% of all global deaths (World Health Organization, 2015a). The global deaths for diabetes were 1.5 million people in 2014; 9% of all adult deaths (World Health Organization, 2015b). In New Zealand, cerebrovascular disease and ischaemic heart disease – both components of CVD – accounted for 8,199 deaths in 2011; 27% of all deaths. Diabetes accounted for 835 deaths in the same period; 2.8% of all deaths (Ministry of Health, 2014a). Combined, both of these diseases account for 1 in 3 deaths in New Zealand.

The financial burden of MetS outcomes are unclear due to a lack of recent published research. Although now dated, Scott, White, and Scott (1993) estimated the tangible costs of coronary heart disease, such as costs of hospital stays, ambulance and pharmaceuticals, to be $179 million for the year of 1992. Intangible costs, such as changes in quality of life or loss of employment, were estimated to be up to $246 million in the same period (Scott et al., 1993). Tangible costs for ischaemic stroke in 1992 were $140 million (Scott & Scott, 1994). For 2008 the costs for T2DM were $600 million, an increase of $350 million in just 7 years (Diabetes New Zealand & PricewaterhouseCoopers, 2008). While these figures are outdated, they allow an understanding of the escalating costs due to increased prevalence of MetS. Adjusting these figures for inflation (http://www.rbnz.govt.nz/monetary_policy/inflation_calculator/), the costs of care for stroke, CVD and T2DM may be more than $1 billion dollars per annum in 2015.

More recent estimates of the financial burden of ischaemic heart disease suggest that the costs associated with hospital care, general practitioner costs and pharmaceuticals is an estimated $287 million per annum (National Health Committee, 2014). Estimates from the Auckland District Health Board estimate the national costs for coronary heart disease to be between $307 and $467 million per annum, with the national costs for stroke to be between $100 and $150 million per year (Auckland District Health Board, 2011). These cost estimates are for hospital visits and pharmaceutical intervention and do not take into account the financial costs of loss of quality of life.
or loss of employment. While the true financial burden of MetS is difficult to specify due to lack of data, the total cost to the country is likely to be substantial.

The burden of disease is commonly measured in “disability-adjusted life years”. The measure is a combination of “years of life lost” – the number of years lost from early death – and “years lived with disability” – the number of years of lost health while living with ill-health. In 2006 in New Zealand, 955,000 years of healthy life were lost; 51% as a result of death and 49% as a result of non-fatal outcomes. Coronary heart disease was the number one cause of loss of health, accounting for 89,159 disability-adjusted life years (9.3% of total). Health loss from stroke, ranked third, accounted for 37,688 disability-adjusted life years (3.9% of total) and diabetes, ranked fifth, accounted for 28,800 years lost (3%) due to death or disability (Ministry of Health, 2013b). Each year of life lost represents considerable financial costs, as well as personal loss for family members and ongoing implications for those caring for members of the community living with disability.

1.4.3. Prevalence

In the United States, it is estimated that the syndrome affects 24% of the adult population (E. S. Ford, Giles, & Dietz, 2002) using the ATPIII (2001) criteria. Although now dated, Gentles et al. (2007) provides data that gives an indication of prevalence in the New Zealand context. Gentles et al. (2007) estimated that in the Auckland population, MetS was present in 32% of Maori adults, 39% of Pacific Island adults and 16% of European adults aged 35-74. The criteria for MetS diagnosis was not reported by Gentles. Simmons and Thompson (2004) also assessed the prevalence of MetS within the Auckland population. Their study of 1,562 non-diabetic South Auckland residents aged >40 years used the ATPIII (2001) criteria to assess the population at risk. They found that among Maori and Pacific Island peoples, 80% of the sample had at least 2 components of MetS and 50% were able to be diagnosed under the ATP III criteria. In European peoples, 50% of females and 25% of males had at least 2 components and MetS diagnosis could be made in 15% of females and 25% of males.

It is difficult to apply the Auckland MetS prevalence findings to the entire country due to the diversity of cultural, physical activity and dietary differences across New Zealand regions. For example, the 2011-2013 Health Survey (Ministry of Health, 2013a) showed that the rate of adequate physical activity (>150 mins/week) ranged from 49.5% in Northland to 36.8% of adults in Counties Manukau. Dietary variations may also create disproportionate rates of MetS throughout the country. In the Nelson-Marlborough district the prevalence of adults meeting vegetable intake guidelines (89.0%) and fruit intake guidelines (63.7%) is greatly different to that of Waitemata (55.7% and 57.8% respectively) (Ministry of Health, 2013a). Cultural and ethnic diversity, particularly
in relation to physical activity, can also influence the prevalence of MetS. Obesity and lack of physical activity are both more prevalent in Pacific Island and Maori peoples (Ministry of Health, 2014b). The increased prevalence of obesity and decreased levels of physical activity may lead to a higher rates of MetS in Auckland, where 30% of Pacific Island peoples and 25% of Maori peoples live, compared to 9% Pacific Island and 10% of Maori peoples living in Wellington (Statistics New Zealand and Ministry of Pacific Island Affairs, 2010; Statistics New Zealand, 2014). Whilst Auckland MetS statistics cannot translate directly to the entire country, a broader understanding might be reached by examining health statistics for individual markers of MetS from the New Zealand Health Survey 2013/14.

The 2013/14 New Zealand Health Survey (Ministry of Health, 2014b) revealed that of the 13,000 adults sampled (aged 15 years and over), 16% were receiving pharmaceutical treatment for hypertension and 11% were receiving treatment for high cholesterol. Other findings showed that 2% of the sample had experienced a stroke, 30% were obese – body mass index (BMI) >30 km/m² – and 6% had been diagnosed with a form of diabetes; although the authors do not state whether this is limited to Type I, Type II or includes those in a prediabetic state (Ministry of Health, 2014b). Whilst these numbers represent a substantial proportion of the population, it is highly likely that many of these individuals will experience a combination of the markers of MetS which, while relevant to MetS, are not of sufficient clinical importance to be included in the survey results. For example, a non-smoking male aged 55-64 with systolic blood pressure of 160 mmHg and hypercholesterolaemia expressed in a cholesterol:HDL cholesterol ratio of >8, is classified as having a ‘moderate 10-15%’ 5 year risk according to The New Zealand Primary Care Handbook (New Zealand Guidelines Group, 2012). In this same individual, MetS criteria (Alberti et al., 2009) would be met for hypertension and it would be very likely that criteria be met for HDL cholesterol. However, in this scenario, the Handbook suggests lifestyle-based changes with no pharmaceutical intervention, therefore missing classification for hypertension in the Health Survey results.

One third of the New Zealand population is obese (Ministry of Health, 2014b) and therefore meets at least one criteria for MetS diagnosis (Alberti et al., 2009). Given that obesity is a strong predictor for hypertension, hypertriglyceridaemia, CVD and diabetes, it may be that an epidemiological study in New Zealand could discover that the incidence of MetS is significant. By comparing the prevalence of MetS in an Australian study by Cameron, Shaw, and Zimmet (2004) – 9.5% for males and 17.2% for females – and extrapolating to include New Zealand obesity and Auckland MetS statistics, it is possible that the prevalence of MetS across the entire New Zealand population may be between 20% and 30%. To be confident of the exact statistics it is important that further objective data be obtained through studies focused on the broader New Zealand context.
1.4.4. Features of metabolic syndrome

The factors involved in the classification of MetS are closely linked - influencing each other collectively via mechanisms that are not currently well understood. As research focuses, a developing picture emerges of a ‘dangerous quartet’ of metabolic changes.

Conventional thinking suggests that long periods of sedentary behaviour (Hamilton, Hamilton, & Zderic, 2007) and excess energy intake (Després & Lemieux, 2006) are producing an obese population. Normally, caloric surplus is stored as triglycerides and cholesterol esters in subcutaneous adipocytes for use in caloric-deficient periods. In some individuals, such as those with insulin resistance or those who lack subcutaneous adipocytes, triglycerides can be stored in skeletal muscle, as well as in viscera around the liver, heart, pancreas and other organs (Després & Lemieux, 2006). This hallmark appearance of central obesity, as a result of an ectopic fat distribution of organ triglyceride and visceral adipose tissue surplus, has more serious negative health effects than the cosmetic aesthetics of modern society demand. Based on the evidence base, it is considered that factors predisposing people to visceral obesity can include age, lack of physical activity, genetics, ethnicity, sex steroids and oestrogen deficiency at menopause. These predisposing factors can result in disproportionate fat storage and visceral-obesity even in non-obese individuals (Carr & Brunzell, 2004).

Adipocytes are not only efficient in the storage of excess fats, but they are also important endocrine-producing cells. Of the many adipocytokines produced to help maintain lipid homeostasis, several products of adipocytes have been identified to influence metabolic health. Pro-inflammatory marker release of interleukin-6 and tumour necrosis factor-α from adipocytes is higher in obese patients than non-obese patients, particularly when visceral obesity is present. Unlike subcutaneous adipocytes, these pro-inflammatory markers released from visceral adipocytes drain directly into the portal vein and towards the liver, where they result in an increased production of C-reactive protein (Fontana, Eagon, Trujillo, Scherer, & Klein, 2007). Collectively C-reactive protein, interleukin-6 and tumour necrosis factor-α are circulated, promoting a system-wide inflammatory response which is a classic marker for metabolic disturbance.

Conversely, of the many serum adipocytokines released by subcutaneous fat storage in healthy people, adiponectin is seen to provide positive benefits to metabolic health. In human and mouse models, normal levels of adiponectin found in non-obese people causally decreases the development of insulin resistance, as well as decreases the risk of atherosclerosis, improving lipid oxidation and vasodilation function throughout the body (Després & Lemieux, 2006; Ryo et al., 2004). In patients with central obesity, adiponectin levels are decreased in both the peripheral veins
and the portal vein (Fontana et al., 2007; Ryo et al., 2004; Yamauchi et al., 2001). This lowered level of adiponectin may have an important influence on the development of MetS as a result of obesity, as the natural protective mechanisms mediated by adiponectin are lost, leading to higher risks of T2DM in obese patients.

Systemic inflammatory response may be more influential on metabolic health than first expected, as explained by Odegaard and Chawla (2013). Nutrients are commonly stored in the liver, white adipose tissue and muscles, where these ‘metabolic professionals’ are able to quickly release energy in periods of demand. Dietary overload leads to cellular break-down and release of nutrients into the extracellular matrix. It is believed that the inflammatory signalling from cellular death of storage cells, such as adipose tissue, inhibits local and systemic insulin signalling as well as recruiting macrophages. It has been seen in obesity-induced adipocyte storage that the macrophage population increases from approximately 10% of adipose tissue normally, to 50% of adipose tissue in obese subjects, further amplifying the insulin-suppressing effects created by a system-wide inflammatory response (Odegaard & Chawla, 2013).

Several mechanisms may lead to hypertriglyceridaemia, although these processes are currently poorly understood. In cases of central obesity or primary insulin resistance, the visceral adipose tissue has a high non-esterified fatty acid turnover and subsequent release into the portal vein. Non-esterified fatty acid overload of an insulin-resistant liver results in higher hepatic synthesis of triglycerides into the system and subsequently the development of hypertriglyceridaemia (Grundy, 1999). Furthermore, it is thought that this fatty acid overload at the liver leads to an increased production of apolipoprotein B. Apolipoprotein B is the structural binder of chylomicrons, very-low density lipoprotein and LDL cholesterol; normally referred to in the lay press as ‘bad cholesterol’. Apolipoprotein B is an atherogenic lipoprotein and contributes directly to atherosclerosis. It is likely that the increased production of triglyceride-rich very-low lipoprotein cholesterol and small-particle LDL cholesterol result in atherogenesis as they easily pass into the arterial wall where proteoglycan binding and macrophage response occurs (Carr & Brunzell, 2004; Van Gaal et al., 2006).

Ongoing debate exists regarding the central feature of MetS and whether insulin resistance or central obesity provides the strongest correlation between all other features. Alternatively, it has been argued that all traits are largely independent and that diagnosis of MetS should abandon hierarchy and place equal emphasis on all features (Anderson et al., 2001). Insulin resistance increases central adipocytes and skeletal triglyceride storage (Després & Lemieux, 2006). Hepatic insulin resistance, in combination with central adiposity, leads to increased free fatty acids release and hypertriglyceridaemia (Grundy, 1998). This cycle is complete when excess-free fatty acid circulation promotes the further development of insulin resistance, as well as further promoting the
development of hypertriglyceridaemia by down-regulating the function of lipoprotein lipase (Eckel et al., 2005). Finally, the decreased levels of adiponectin seen in those with central obesity also promote greater insulin resistance, further increasing central adiposity.

As insulin resistance is a strong predictor for raised cholesterol, triglycerides, blood pressure and increased risk for CVD (Alexander, Landsman, & Teutsch, 2000; Zavaroni et al., 1987), it is likely that without intervention the presence of insulin resistance contributes to and is influenced by the other markers of MetS in a close grouping that are all predisposed and aggravated by one another.

Finally, blood pressure may too be influenced by insulin resistance, hypertriglyceridaemia and central obesity. The vasodilatory effects of insulin are lost in resistant individuals when blood vessels stop dilating in response to insulin secretion and instead abundant free fatty acids create vasoconstriction (Kuroda et al., 1999). Paired with upregulated sodium retention as a result of high plasma insulin levels (Eckel et al., 2005), increased sympathetic drive and membrane transport interference (DeFronzo & Ferrannini, 1991), insulin resistance increases blood pressure. This high blood pressure, combined with high levels of atherogenic lipoproteins found in MetS and a system-wide inflammatory response (Odegaard & Chawla, 2013), eventually leads to the development of hypertension and atherosclerotic plaque formation (Grundy, 1999).

1.4.5. The metabolic effects of sitting down

In recent years, research has discovered a correlation between sedentary behaviour, such as time spent sitting or lying down and the risk factors for MetS. Outcomes of long periods of sedentary behaviour include increased BMI (Mummery et al., 2005), increased waist circumference (Wijndaele et al., 2009) and increased blood glucose (Healy et al., 2007). Beyond the measure of individual components, the diagnosis of MetS in adults who spent more time sitting down is higher than those who are more active (Bertrais et al., 2005; Wijndaele et al., 2009). This link between sedentary behaviour and metabolic health outcomes is compelling and suggests that, in addition to existing interventions such as medication, lifestyle or dietary changes, we might find benefit in changing the amount of time we spend sitting down.
1.5. Sedentary behaviour

1.5.1. Defining sedentary behaviour

Sedentary behaviour is distinct from other forms of activity, such as light intensity physical activity and moderate or vigorous intensity physical activity. Sedentary behaviour, from the Latin word *sedere* – to sit, is defined as a waking behaviour with a very low-energy expenditure <1.5 metabolic equivalents, that occurs when laying down or sitting still (Ainsworth et al., 2000; Sedentary Behaviour Research Network, 2012). Time spent sitting does not fall into the continuum of physical activity intensity. Instead, it appears that sedentary behaviour has unique and independent effects on many health outcomes (Hardy et al., 2012).

A large volume of data are available as to the benefits of moderate to vigorous physical activity and very precise recommendations have been made by authorities such as the American College of Sports Medicine and the American Heart Association about the exercise requirements for adults (Haskell et al., 2007). The importance and influence of sedentary behaviour and light intensity physical activity; however, have only recently been recognised. Assessing the sedentary behaviour patterns in adults is less obvious and what research that does exist on the subject is often focused on adolescents. This focus on adolescent behaviour is perhaps as a result of technological developments in screen-based entertainment, such as computer games, which compete with physical activity (Biddle, 2004) and results in research being rarely focused on sedentary adults.

Sedentary behaviour is classified as activity that requires 1 metabolic equivalent, that is, the energy expended by sitting still (Ainsworth et al., 2000). Light intensity physical activity is considered to be that which expends <3.0 metabolic equivalents and might occur whilst doing such activities as walking slowly around the office or standing. Moderate physical activity is defined as that between 3.0 and 6.0 metabolic equivalents and would occur whilst doing such activities as walking briskly, housework or playing golf. Vigorous intensity activity is that which expends >6.0 metabolic equivalents, such as jogging, swimming or performing heavy manual labour. For those who work in offices, such as professionals (law, accounting or finance) or clerical/administration staff, it is likely that a large part of the day is comprised of sitting; sitting whilst commuting, sitting whilst at work, sitting for lunch or sitting in front of the television in the evening.

In a comprehensive review by Rhodes, Mark and Temmel (2012), the impacts of sedentary behaviour was correlated against common biopsychosocial traits. They examined 109 peer-reviewed articles that investigated the correlates of sedentary behaviour in non-clinical adults, independent of physical behaviour. Their review found that television-based sedentary behaviour increases with age and is also higher in unemployed people. Computer-based sedentary behaviour
was higher in young adults rather than middle-aged or older adults, as well as those with higher levels of education. Further observations by Rhodes explain that television viewing (but not computer use) appears to be linked to decreased physical activity, increased depressive symptoms and lower psychological well-being.

1.5.2. The "sitting epidemic" and occupational sedentariness

A comprehensive large-scale study (n = 49,493, age 18-65) by Bauman et al. (2011) used the responses from the International Physical Activity Questionnaire of 20 countries to create a snapshot of the descriptive epidemiology of sitting. They state the mean sitting time for all countries was 5.8 h/day with no differences found between males and females. Adults aged 19 to 39 years were likely to spend more time sitting per day than adults >40 years old and those with >13 years of education were more likely to sit than those with <13 years education.

Bauman et al. (2011) reveal that in New Zealand (n = 1447), the median sitting time was 4 h/day. By quintile, 21.5% of those sampled sat <3 h/day, 28.7% sat between 3 h/day and 4 h/day, 21.9% sat between 4 h/day and 6 h/day, 14.3% sat between 6 h/day and 9 h/day and 13.6% of the sample sat for >9 h/day. Similar to international findings, no significant differences existed between males and females for median sitting time. Significantly greater median sitting time was observed for those with >13 years education (5/h day) than for those with <13 years education (4 h/day) and significantly greater sitting time was observed for those aged 18 to 39 (5 h/day) than for those aged >40 years (4 h/day).

Less data exist for sitting time by specific periods of the day. Half of the New Zealand adult population sit for at least 4 h/day, about the same percentage of the population who are considered to be physically inactive, i.e. those who fail to meet the minimum of 30 minutes a day of moderate-intensity physical activity (Ministry of Health, 2014b). However, it is not clear how much of this total sedentary time is comprised of occupational sitting, leisure time sitting or time spent sitting whilst commuting to work.

In a cross-sectional survey of Dutch workers (n = 7720) between 2000 and 2005 (Jans, Proper, & Hildebrandt, 2007), sedentary time was examined by period of the day and also by industry. On average, Dutch workers spent 7 hours each day sitting – comprising of 30% (2 hours) at work, 5% (21 minutes) travelling to and from work and 66% (4.7 hours) in ‘other’ sedentary time during the day and evening. Sitting time was higher for full-time workers than part-time workers and the highest levels of sedentary behaviour inside and outside of the workplace were found in professional and clerical occupations.
In a cross-sectional Australian study by Mummery et al. (2005) the self-reported occupational sedentary behaviour of 1579 full-time workers in Queensland found that the average occupational sitting time was >3 h/day and in 25% of the sample, the average occupational sitting time was >6 h/day. It was found that sitting time was higher in both sexes for professional (4.1 h/day) and ‘white-collar’ workers (3.5 h/day), than for ‘blue-collar’ workers (2.3 h/day) (Mummery et al., 2005).

It is therefore plausible to make broad comparisons between Australia and New Zealand due to close historical, cultural, economic and political similarities. In New Zealand in 2014, there were 2.4 million people in employed work, with roughly 60% of these working >35 h/week (Statistics New Zealand, 2015). Professional and administrative roles – managers, professionals, clerical and administrative workers – account for 52% of the current New Zealand workforce. If 60% of those workers are full-time, working 35 hours or more a week, then it is plausible that a third of New Zealand adults in full-time employment spend an average of 3.5 to 4.1 h/day sitting in the workplace alone.

1.5.3. Measuring sedentary behaviour
Measurement of sedentary time and physical behaviour is complicated and a number of mechanisms exist to do so – each with their own advantages and disadvantages. Hardy et al. (2012) describe the different options available and their benefits and limitations (see Table 1.5.1).

When assessing sedentary behaviour on a large scale with a number of participants, subjective questionnaires may be used to assess physical activity ‘yesterday’ or ‘last Tuesday’ or ‘in a typical week’. Whilst this method is simple for participants and allows for scaling, it is also unreliable due to its subjective nature. For example, the New Zealand Physical Activity Questionnaire and the International Physical Activity Questionnaire both show an overestimation of physical activity levels when compared to objective accelerometer data (Boon, Hamlin, Steel, & Ross, 2010). Additionally, participants may be forgetful if the period of time is too long or answers may be biased as the participant responds with what they feel should be the norm or the socially acceptable answer.

Observation methods to identify sedentary behaviour may be done using video or with a data collector present in the room. Both these methods allow the researcher to gain useful information of the sedentary position of the participant as well as context to the activity, e.g. ‘participant is sitting at a workstation using a computer’. This method, whilst good for short periods of time (such as 24 hours), is time consuming for the data collector and may be considered too invasive for many participants. This method may also influence the behaviour of participants resulting in inaccurate data. Described as the ‘Hawthorne effect’, observation of behaviour can result in a change of participant behaviour (McCarney et al., 2007).
Physical activity and sedentary behaviour information may also be captured using digital data devices, such as an accelerometer, inclinometer or screen monitoring software. All three can provide highly accurate data, but lack the context of the activity and behaviours. Accelerometers capture robust data regarding physical activity, which are then analysed and movement counts can describe energy expenditure, metabolic equivalents and other physical activity information using established cut-points such as the popular Freedson (1998) or Puyau (2002) criteria. Inclinometers use angle measurement in x, y and z axes to determine the position of a participant’s thigh or waist and count time spent standing, walking or sitting/lying. Both of these measurement methods require the participant to wear a small data capture device, which may be uncomfortable to participants over a long period of time. Devices are also prone to failure and need to be monitored carefully for battery life and correct operation.
1.6. Sedentary behaviour and health outcomes

1.6.1. Psychological health

More time spent in sedentary behaviour is associated with higher levels of psychological disorders, such as anxiety, depression or distress (Kilpatrick, Sanderson, Blizzard, Teale, & Venn, 2013; Sanchez-Villegas et al., 2008; Teychenne, Ball, & Salmon, 2008). In a study of 10,381 Spanish graduates, Sanchez-Villegas et al. (2008) found that those with >42 h/week of sedentary time were 31% more likely to develop a psychological disorder than those who spent <10 h/week in sedentary behaviour.

In the workplace, sedentary behaviour has implications for psychological distress. A Tasmanian survey of 3,367 government employees found that compared to those occupationally sitting for <3

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**Table 1.5.1** – Limitations and considerations associated with measuring sedentary behaviour. Modified from Hardy et al. (2012).

<table>
<thead>
<tr>
<th>Source of error</th>
<th>Accelerometers</th>
<th>Inclinometers</th>
<th>Screen Monitoring</th>
<th>Observation</th>
<th>Self-Report</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data entry and data reduction complexity</td>
<td>High – data downloaded to computer and reduced using specialised software</td>
<td>High – data downloaded to computer and reduced using specialised software</td>
<td>Low – data recorded by device</td>
<td>Low – manual data entry table</td>
<td>Low – manual data entry table</td>
</tr>
<tr>
<td>Method</td>
<td>Objective Prospective/Current</td>
<td>Objective Prospective/Current</td>
<td>Objective Prospective/Current</td>
<td>Objective Prospective/Current</td>
<td>Subjective. Retrospective</td>
</tr>
<tr>
<td>Data captured</td>
<td>Counts body movement (accelerations) in real time; algorithms used to indicate level of activity</td>
<td>Time spent in different postures, including sitting, in real time. Number of sit-to-stand transitions</td>
<td>Total time spent viewing electronic screen for each individual</td>
<td>Time spent in different posture/intensity, including sitting/sedentary</td>
<td>Average frequency and/or duration of overall sitting or of specific sedentary behavior</td>
</tr>
<tr>
<td>Cost</td>
<td>High financial</td>
<td>High financial</td>
<td>High financial</td>
<td>High financial and time</td>
<td>Low financial, moderate time</td>
</tr>
<tr>
<td>Data captured</td>
<td>Small to large</td>
<td>Small to large</td>
<td>Small</td>
<td>Small</td>
<td>Small to large</td>
</tr>
</tbody>
</table>
h/day, men who sat at work for >6 h/day were more prone to moderate psychological distress (prevalence ratio = 1.90, 95 CI = 1.22 to 2.95) and women who sat for >6 h/day were more prone to moderate (prevalence ratio = 1.25, 95% CI = 1.05 to 1.49) and high levels (prevalence ratio = 1.76, 95CI = 1.25 to 2.47) of distress. These results were found to be independent and unaffected by levels of leisure time physical activity or by levels of self-reported work-related stress (Kilpatrick et al., 2013). Interestingly, in a study of 1,995 adults using self-reported sedentary behaviour and objective pedometer data, long periods of physical activity in the workplace for women (>10 h/week) were associated with twice the level of depression compared to those who were completely sedentary in the workplace (McKercher et al., 2009). This research did not suggest occupational types, but it is unlikely that office workers are exposed to such long periods of occupational physical activity. What it may represent; however, is that influence on psychological distress of physical activity and sedentary behaviour is not necessarily on a continuous scale and may instead be unique.

With all of the previously discussed research findings, it is important to note that no causal relationship is implied between sedentary behaviour and psychological state due to the cross-sectional nature of the research. It may be that altered psychological states drive sedentary behaviour or that sedentary behaviour in conjunction with anxiety or depressive predisposition only aggravates the symptoms. Additionally, it may be that while physical activity ameliorates negative psychological health such as depression (McKercher et al., 2009; Teychenne et al., 2008), sedentary behaviour is not necessarily on a continuous scale and may instead be unique.

1.6.2. Cancer risk

In a study of 488,720 participants, assessing the impact of sedentary behaviour on colon and rectal cancer, Howard et al. (2008) found that overall sedentary time was associated with an increase in colon cancer risks. Men who spent >9 h/day in sedentary screen time experienced an increase in the risk of colon cancer (risk ratio = 1.61, 95% CI = 1.14 to 2.27) compared to men who sat for <3 h/day. The effects of sedentary behaviour are also present for other cancers. An increased risk (hazard ratio = 1.55, 95% CI = 1.08 to 2.22) for ovarian cancer was seen in women who spent > 6 h/day in sedentary behaviour compared to <3 h/day (Patel, Rodriguez, Pavluck, Thun, & Calle, 2006). Similar effects can be seen on the risks for endometrial cancer rates. In a study of 70,000 women, it was found that sitting for 5-6 h/day increased the risk of endometrial cancer (risk ratio = 1.29, 95% CI = 1.02 to 1.63), with higher increases in risk for those sitting >7 h/day (risk ratio = 1.23, 95% CI = 0.96 to 1.57) when compared to women who sat <3 h/day (Gierach et al., 2009). Importantly, these risks were independent of all vigorous activity, suggesting that any direct influence of sedentary behaviour on cancer may occur regardless of physical activity levels.
1.6.3. **Prolonged sitting and metabolic health**

In one of the first published studies examining sedentary behaviour, it was recognised that excess sitting time was harmful to health and well-being. Morris and Crawford (1958) concluded that those individuals employed in largely sedentary jobs (such as bus drivers or telephonists), had twice the rate of CVD as their standing counterparts - bus conductors and mail deliverers. Nearly 50 years later there is irrefutable evidence that sedentary behaviour is associated with an increased risk of T2DM, CVD, cardiovascular mortality and all-cause mortality (Dunstan et al., 2010; Matthews et al., 2012; Stamatakis et al., 2011; Van Gaal et al., 2006).

The beneficial effects of physical activity have been well documented and there is irrefutable evidence to demonstrate that regular physical activity can help to prevent myriad diseases including CVD, diabetes and hypertension (Warburton, Nicol, & Bredin, 2006). In recent years, a growing pattern is emerging in research studies suggesting that the effects of sedentary behaviour are unique and independent of the levels of physical activity and that reducing sedentary behaviour levels may be as important as increasing daily physical activity levels (Healy, Dunstan, et al., 2008).

Sedentary behaviour clearly influences the markers of metabolic health. For example, Mummery (2005) found that men who spent >6 h/day in occupational sitting were twice as likely (odds ratio = 1.92, 95% CI = 1.17 to 3.17) to have a BMI >25 kg/m² than those who sat <45 min/day. Sedentary behaviour was also found to be associated with increased waist circumference and decreased HDL cholesterol in men and increased waist circumference and blood pressure in women, independent of leisure time physical activity (Wijndaele et al., 2009). Research has also demonstrated that blood glucose status is linked with sedentary behaviour. As a subset of the AusDiab study, Healey et al. (2007) used accelerometers to measure physical behaviour against 2-hour plasma glucose tests. It was found that sedentary behaviour was positively associated with higher 2-h plasma glucose levels and that light intensity physical activity and moderate to vigorous physical activity were associated with lower 2-h plasma glucose levels.

The effects of sedentary behaviour are not limited to individual markers of MetS, but also to increased prevalence of actual diagnosis. In a French study of 3,834 men and women, Bertrais et al. (2005) saw that after adjusting for self-reported physical activity there was an increased risk for MetS (ATPIII criteria) for men (odds ratio = 1.39, 95% CI = 0.97 to 1.99) and women (odds ratio = 3.3, 95% CI = 2.04 to 5.34) for >3 h/day sedentary behaviour compared to <2 h/day.

The effects of sedentary behaviour are also implicated in changes to overall health. In a widely cited study, Stamatakis et al. (2011) compared the results of 4,512 respondents from the 2003 Scottish Health Survey with the Scottish Information Division Database (of hospital visits and
deaths) up until 2007. By examining sitting time (measured by self-reported screen time) against cardiovascular events and all-cause mortality, they concluded that those who spent >4 h/day sitting had increased risk of cardiovascular events (hazard ratio = 2.3, 95% CI = 1.33 to 3.96) and increased risk of mortality from all-causes (hazard ratio = 1.52, 95% CI = 1.06 to 2.16) when compared to those who sat <2 h/day. When adjusted for physical activity, it was seen that these risks were not attenuated, suggesting that moderate and vigorous intensity physical activity levels did not impact on the risks. Mediating variables for cardiovascular events were also examined and it was found that 25% of events could be explained by C-reactive protein, BMI and HDL cholesterol. Interestingly, it was found that C-reactive protein levels were 3-fold higher for those who spent >4 h/day sitting compared with those who spent <2 h/day sitting (Stamatakis et al., 2011). This suggests that inflammatory and metabolic pathways may explain a link between sedentary behaviour and metabolic illness.

Changes to C-reactive protein were also seen in a study of 4,757 American adults using objective accelerometer data. After adjusting for physical activity, total sedentary behaviour was associated with deleterious changes to waist circumference, HDL cholesterol, C-reactive protein, triglycerides and insulin. Furthermore, independent of physical exercise, breaks in sedentary time were positively associated with improvements to waist circumference, C-reactive protein and fasting glucose (Healy et al., 2011).

A study by Wijndaele et al. (2009) used a continuous scoring model for MetS, in place of binary assessment, to assess the influence of questionnaire-reported sedentary behaviour (n=992, age 18-75) on the markers of this syndrome. As with studies previously mentioned, they concluded that MetS risk was positively associated with sedentary behaviour in both men and women, independent of leisure time physical activity. By using the same continuous MetS scoring model, Healy et al. (2008) used objective accelerometer data to analyse relationships between metabolic health and sedentary behaviour, light intensity physical activity and moderate to vigorous physical activity in 169 participants (age 30-87) of the AusDiab study. They found that on average, participants spent >90% of accelerometer wear time in sedentary behaviour or light intensity physical activity and that sedentary behaviour was positively associated with increased MetS risk and increased waist circumference, independent of moderate to vigorous physical activity.

The strong body of evidence suggests that the more time spent in sedentary activity, the greater the negative effects on metabolic health. However, it is worth noting that research conducted by Healy et al. (2008) showed that, regardless of total daily sedentary time, the total number of breaks in sedentary activity was associated with a significant decrease in the risks of MetS such as low HDL cholesterol, increased waist circumference, increased and 2-h plasma glucose levels, even after
adjusting for intensity of breaks and moderate to vigorous physical activity. This finding alone does not implicitly suggest that total daily occupational sitting time should be left unconstrained as long as sitters stand up every 15 minutes. Instead, it could be argued that a multifactorial approach should be taken, where total sitting time is reduced through workstation alternatives and recommendations are put in place to break up prolonged periods of sitting where employees are required to do so.

Important learnings must be taken from this research. Firstly, sedentary behaviour is positively correlated with deleterious changes in both specific markers of MetS, as well as the health outcomes of MetS such as diabetes and CVD (Bertrais et al., 2005; Healy et al., 2007; Van Gaal et al., 2006). Secondly, many of these negative effects on metabolic health are still present even after adjusting for levels of physical activity in both subjectively and objectively measured studies (Healy et al., 2011; Stamatakis et al., 2011; Wijndaele et al., 2009). Being active for 150 minutes per week is not negating the harm of time spent sitting. Instead, these data make a clear case that a focus must be made to decrease total sedentary time in order to assist with the high levels of poor metabolic health.

1.6.4. Mechanisms of harm in sedentary behaviour

Sedentary behaviour has unique effects on the risks for disease that are independent of the beneficial effects of physical activity (Dunstan et al., 2005; E. S. Ford, Kohl, Mokdad, & Ajani, 2005). Physical activity may not be a scale from sedentary to vigorous intensity; instead the mechanisms involved in sedentary behaviour are likely to be entirely different from the mechanisms involved in physical activity. Even in people who do not actively exercise (roughly half of the New Zealand population), a large amount of light intensity physical activity is achieved throughout the day by activities such as standing whilst cooking, running to catch the bus or walking to collect the printing in the workplace. Since light intensity physical activity is inversely related to sedentary time, as well as the risk factors for metabolic disease (Healy et al., 2007), it should be recognised that as well as extolling the virtues of moderate to vigorous physical activity, we must also acknowledge the benefits of light intensity physical activity and fight the growing societal trend towards sedentary behaviour.

Sitting, as an activity, requires less energy expenditure than standing, walking or moving. In assessing the energy expenditure between standing up and sitting down, Reiff, Marlatt and Dengel (2012) collected and measured expired gasses from young adults (n=10, mean age 22.8 years old) using sitting workstations and then standing workstations. Although the results were small, significant increases were detected for caloric expenditure whilst standing, compared with sitting.
From their data, participants would have increased energy expenditure by 20 kcal/hour. Whilst this number is a fifth of the energy in that of a medium-sized banana, it is perhaps representative of wider physiological changes that occur whilst in light intensity physical activity.

Standing recruits a large number of muscle contractions in the biggest muscle groups in the body. This increase of muscle fibre recruitment during postural muscle demand when standing may produce beneficial cellular processes that ameliorate the markers for disease. One such mechanism is the involvement of lipoprotein lipase (Hamilton et al., 2007). In rat models, hind-leg unloading showed a substantially lower level of lipoprotein lipase activity in slow-twitch and fast-twitch muscles compared to standing periods with hind-leg loading. Additionally, triglyceride uptake into skeletal muscles was also substantially higher in standing rats than in inactive rats. Lipoprotein lipase down-regulation from sedentary behaviour leads to a reduced ability of muscles to clear chylomicrons from the blood, leaving the plasma rich in triglycerides.

Limited evidence suggests that skeletal muscle GLUT4 receptors may be influenced by increases in sedentary behaviour. Following bodyweight-supported treadmill training, 9 participants with incomplete spinal cord injuries showed improvements in muscle GLUT4 function (Phillips et al., 2004). The glucose transporter is normally upregulated by physical exercise; however, following low weight loading the researchers saw a 126% increase in skeletal muscle GLUT4 content as well as improved oral glucose tolerance tests (Phillips et al., 2004). By increasing light intensity physical activity, there is potential for increased GLUT4 function, particularly in the large postural leg muscles, therefore aiding glucose regulation. Importantly, as GLUT4 function is upregulated through skeletal muscle contraction independent of insulin action, the up-regulation of the glucose transporter may aid in metabolic regulation even in insulin resistant-individuals.

1.7. Conclusion

Metabolic Syndrome is a cluster of clinical signs occurring commonly together that increase risks of predisposition to CVD, T2DM, stroke and other preventable diseases. Although continuing international discussion occurs over the definition of MetS, the current knowledge defines it as a homeostatic imbalance, leading to central obesity, elevated blood pressure, raised blood glucose, triglycerides and decreased HDL cholesterol. Whilst it is difficult to accurately comprehend the impact in New Zealand, the syndrome may occur in 20 to 30% of the adult population.

Sedentary behaviour involves physical activity of low energy expenditure, such as sitting or lying down. In New Zealand, 50% of the population sit for more than 4 hours/day - enough to increase morbidity. Sitting is more prevalent in professional or administrative jobs and in young adults with higher levels of education. As increasing use of technology tends to decrease the level of physical
activity, these young and educated individuals are likely to experience the greatest negative influence on health in the next decade.

Metabolic syndrome appears to be modified by sedentary behaviour. The result of an excess of sedentary behaviour can be seen in the increased risks of obesity, lowered HDL cholesterol, increased blood pressure and blood glucose. Furthermore, sedentary behaviour increases the risk of CVD as well as all-cause mortality. Irrefutable evidence suggests that the physiology of sedentary behaviour is different to that of physical activity and that these risks are not affected by levels of physical activity outside of sedentary periods.

The mechanisms by which sedentary behaviour positively changes risk of MetS are poorly understood. By decreasing sedentary behaviour and increasing light intensity physical activity (such as standing or walking), we might attenuate the harmful effects of sitting down. In addition, where occupational sitting is mandated for any length of time, it has been recommended that bouts of prolonged sitting are broken up with regular periods of standing, potentially providing further beneficial influences to the markers of MetS. While this appears to be a sensible suggestion, further objective data is needed to confirm. By combining workstation modification as well as behavioural changes, the rising trend towards sedentary behaviour and metabolic imbalance may be effectively addressed.
Chapter 2. Changing behaviour through standing workstations. A review of the literature
2.1. Introduction

Decreasing occupational sedentary behaviour, such as that prevalent in the office environment, can occur using a number of different interventions. By utilising an office-wide approach including positive role-modelling and a supportive social environment, changes can be made to sedentary behaviour patterns by promoting active meeting breaks (Yancey et al., 2004) or encouraging ‘active office’ environments (Dunstan et al., 2012) where increased activity is achieved through behaviour change. Previous research undertaken on the adoption of the ‘10,000 step challenge’ has demonstrated that the use of pedometers to increase awareness of physical activity helps to promote the reduction of sedentary behaviour and helps employees meet current daily physical activity recommendations (Le Masurier, Sidman, & Corbin, 2003). These types of interventions, however, succeed only to reduce sedentary behaviour when workers are away from their desks and therefore arguably provide health benefits at the cost of occupational productivity. Extrapolating further, it is fair to assume that a large majority of companies would be unwilling to implement company-wide adoption of physical activity interventions that have the potential to negatively impact the company’s bottom line. Reducing occupational sitting must be effective at decreasing the time spent in sedentary behaviour with minimal negative effects or even positive effects on employee performance and output.

This review looked for original research articles through primary database search or via secondary channels such as reference sections of existing papers. Database searches were performed on Google Scholar, Science Direct, Ebscohost and PubMed. Specifically, research articles that investigated the use of standing or sit-stand workstations in the workplace and that measured physiological and anthropometric changes were closely examined. Changes included those that might influence metabolic health, such as energy expenditure, changes to sedentary behaviour and changes to the markers of Metabolic Syndrome. In addition, articles that examined the user acceptability of sitostand workstations were examined in order to provide context in to the feasibility of this thesis. Seven articles were found matching these criteria (Table 2.4.1). Additionally, this review attempts to provide a brief contextual understanding of both the broader psychological and physiological impacts of sit-stand or standing workstations - in particular the influences on musculoskeletal symptoms, productivity or psychological changes.

2.2. Sedentary behaviour and metabolic risk modification

In many ways, the relative dearth of experimental studies examining the effects of sit-stand and standing workstations demonstrates the novelty surrounding the concept of reducing sitting time, especially in the workplace. It should be recognised that sedentary behaviour reduction does exist in several forms for occupational settings; however, this review will not examine the effects of ‘active-workstations’, such as
treadmill or cycle workstations, as it could be argued that this would not only replace sitting time with light intensity physical activity such as standing, but also introduce moderate intensity activity, which is not a focus during this study.

Four studies examined the energy expenditure differences between sitting down and standing up in the workplace. Evidence was found that standing up for short periods of time significantly increased energy expenditure when compared to sitting down. Rieff et al. (2012) discovered that the use of a standing workstation (1.36 ± 0.20 kcal/min) for 45 minutes resulted in an increased caloric demand of 20.4 kcal/hour when compared to sitting down (1.02 ± 0.22 kcal/min). Similar results were seen by Thorp et al. (2013) over an 8-hour period of standing with an increase of 11.2 kcal/hour (2873 ± 458 kcal vs 2784 ± 403 kcal, t = 8h) and by Buckley, Mellor, Morris, and Joseph (2014) with a gained energy expenditure of 50 kcal/hour over a 3-hour standing period (487 ± 174 kcal vs 313 ± 139 kcal, t = 120min). No significant differences were observed by Speck and Schmitz (2011) for kcal or metabolic equivalent expenditure in their 7-minute intervention. Whilst the results seen by Rieff, Thorp, and Buckley could be considered small, over an 8-hour working day of full-time standing this could arguably equate to 89 kcal to 163 kcal of additional energy expenditure, which is the equivalent caloric expenditure of roughly 5.4 kg of weight gained per year from over-eating by 120 kcal/day (Katan & Ludwig, 2010).

If reducing workplace sedentary behaviour through lifestyle modification is to be achieved, then it is important that interventions are able to decrease the daily sitting time. Studies investigating the effect of time spent in sedentary positions were examined and although the evidence is somewhat limited, the data do suggest that the use of a sit-stand or standing workstation is effective at decreasing daily sitting time. Alkhajah et al. (2012) provided participants with a dedicated sit-stand solution that attached to their current workstations. Using objective accelerometer data, they found that within 1 week, sitting time had reduced by 143 minutes per day compared to a control sitting group. Encouragingly this same decrease was maintained when re-measured after 3 months of standing. Neuhaus, Healy, Dunstan, Owen, and Eakin (2014) similarly observed a reduction in sitting time across two of their intervention groups when compared to a sitting-only control group. In a group receiving a sit-stand workstation alongside a 'multi-component' education program, total daily sitting time was reduced by 89 minutes compared to the control group. In a group receiving a sit-stand workstation only, a reduction of total daily sitting time of 33 minutes was experienced compared to the control group.

It is worth noting that both of the aforementioned studies by Alkhajah and by Neuhaus utilised dedicated standing workstations for their participants, which could arguably be considered a vital mechanism in achieving participatory compliance. Gilson Suppini, Ryde, Brown and Brown (2012) on the other hand, tested the use of standing ‘hot-desks’ in the workplace, whereby participants could temporarily relocate from their existing sitting desk and were encouraged to use the standing ‘hot desk’
workstations for any amount of time. The use of the standing workstations ranged dramatically from 0 h/day to 9 h/day; however, no significant change in sedentary time across the entire group was observed. The perceived barriers presented by ‘hot-desks’ may be too great to see effective uptake. For example, the process of logging off one computer and on to another each day (or multiple times during the day) involves a greater amount of effort than having one dedicated work station. Similarly, workstation availability can become difficult and motivation hampered, if several staff members have set up for the day on a standing workstation and there are only a limited number available. It can therefore be argued that the establishment of dedicated standing workstations in offices is advantageous to the reduction of sedentary behaviour by providing participants with the opportunity to sit or stand at their own will, whenever they wish to do so.

Only two of the reviewed studies examined the effects on the metabolic markers of health through the use of standing up workstation alternatives. As well as measuring changes in sedentary time, Alkhajah et al. (2012) also measured BMI, waist and hip circumferences, body fat composition as well as fasting total cholesterol, HDL cholesterol, triglycerides and glucose across a 3-month standing intervention program. An average increase in HDL cholesterol of 0.26 mmol/L was detected in the intervention group, with no other significant differences observed. Buckley, Mellor, Morris, and Joseph (2014) assessed the post-lunch blood glucose levels of individuals after 185 minutes of sitting and 185 minutes of standing. They found that the postprandial blood glucose levels after standing were 43% lower than after sitting. These results provide encouraging evidence to suggest that replacing occupational sitting time with light intensity physical activity may produce positive metabolic health benefits by reducing the markers for MetS.

2.3. Acceptability, usability and performance effects

Regardless of the reported health benefits of behaviour modification experienced with sit-stand or standing workstations, if the workstation is seen as a detractor from normal productivity or comfort levels it will likely be rejected by both employers and employees as a viable workplace intervention. In a study by Alkhajah et al. (2012) using small ‘add-on’ sit-stand workstations that elevated only the keyboard and mouse, participants reported greatly enjoying the experience and preferred to stand whilst working. However, participants found the design of the desk to be a detractor as it lacked space to rest their hands. Introducing a standing workstation to a work environment must address practical concerns like these to achieve acceptance and buy-in.

Work-related musculoskeletal disorders represent a third of all occupational disorders in the United States, Japan and all Nordic countries, as prolonged periods of sitting can produce back, neck and arm pain as a result of prolonged static postures (Punnett & Wegman, 2004). For decades, we have seen large-
scale investment into the innovation of workplace ergonomics and chairs, which can cost upwards of several hundreds of dollars per product. For standing workstations to be a viable company investment, their use must ideally produce the same or better levels of comfort and potentially a decrease of musculoskeletal symptoms. Pronk, Katz, Lowry, and Payfer (2012) saw decreased upper back and neck pain in participants following the introduction of standing workstations in the workplace and improvements were negated following the removal of the workstation at the end of the intervention. Whilst a decrease in musculoskeletal symptoms was similarly shown by Robertson, Ciriello, and Garabet (2013) in their research on standing workstations, their findings also highlighted the importance of training and education in the overall efficacy of the intervention. Participants with ergonomic education embraced standing over sitting and reported lower discomfort levels and experienced increased standing times compared to a control group who had the opportunity to stand but had received no training.

Sitting for long periods of time increases feelings of moderate to high psychological distress in both men and women (Kilpatrick et al., 2013). Pronk, Katz, Lowry, and Payfer (2012) included psychological assessment in their standing study and discovered that following 4 weeks of standing, participants’ mood-states improved for fatigue, vigour, tension, confusion and depression. The benefits of the standing workstation were further highlighted when participants reported that these improvements in mood-states returned to baseline levels following the removal of their standing workstations.

No effect on speech or typing performance was noted between standing and sitting workstations (Beers, Roemmich, Epstein, & Horvath, 2008; Cox et al., 2011; Ebara et al., 2008), indicating that a standing workstation intervention is unlikely to negatively impact these requirements in the workplace. Enhanced performance effects also appear to be sustained over long periods of time even after the initial ‘novelty’ of a standing workstation has diminished. In their standing study, Pronk, Katz, Lowry, and Payfer (2012) found that participants had greater feelings of focus and productivity whilst standing and that work performance, reinforcing the suggestion that focus could potentially improve as a result of using a standing workstation (Ebara et al., 2008; Grunseit, Chau, van der Ploeg, & Bauman, 2012).

2.4. Conclusion

The installation of standing workstations in the workplace appears to reduce the amount of sitting time and increase the level of standing time, which is still evident after prolonged periods of time. Reducing prolonged sedentary behaviour through the increase of light intensity physical activity may be important in reducing the risk factors associated with MetS leading to CVD, T2DM and stroke. This may be due to the fact that the use of standing workstations not only increases hourly caloric energy expenditure, but also
affects biochemical markers, as seen in the decrease in postprandial blood glucose concentrations in standers compared to sitters.

In order for sit-stand or standing workstations to be embraced as a viable and attractive solution to reducing sedentary behaviour in the workplace, they must be both practical and accessible to their users. The availability and type of standing workstations is important to encourage uptake and good user experience as well. The use of shared ‘hot-desk’ standing workstations is a detractor for various reasons including the motivational barriers of constant relocation and resource scarcity. The size and design of the desk is also important as users should be able to have space to spread out, rest their arms comfortably and stack paperwork at the same level as the keyboard and mouse.

Overall, there appears to be little to no negative influences on workplace performance, psychological mood or musculoskeletal discomfort when using a standing up desk. For users to spend longer periods of time standing up, it is crucial that they feel no increase in fatigue, pain or discomfort. Equally, for employers to implement and encourage the use of standing workstations, it is important that no decrease in work output and performance is experienced by their employees.
<table>
<thead>
<tr>
<th>Study</th>
<th>Sample</th>
<th>Design</th>
<th>Intervention</th>
<th>Age</th>
<th>Environment</th>
<th>Outcome measures</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkhajah et al. (2012)</td>
<td>n=18</td>
<td>Two-arm quasi-experiment. 1 week baseline, 3 month intervention</td>
<td>Sit-stand workstation (addon, dedicated)</td>
<td>20-65</td>
<td>University campus (staff and students)</td>
<td>Average sit/stand/step. BMI. Fat free mass. Fat mass. Waist and hip circumference. Fasting HDL cholesterol, triglycerides, glucose. Self reported outcomes.</td>
<td>2h decrease in sitting time at 1 week and 3 months. Increase in HDL cholesterol compared to observation group (average 0.26 mmol/l)</td>
</tr>
<tr>
<td>Buckley, Mellor, Morris, and Joseph (2014)</td>
<td>n=10</td>
<td>Single group, repeat measures. 1 day baseline, 1 day intervention</td>
<td>Standing workstation (replacement, dedicated). 185 minutes</td>
<td>22-59</td>
<td>Office staff</td>
<td>Capillary glucose - continuous measurement. Overnight fasting glucose. Waist-band accelerometer. Chest-strap heart rate monitor</td>
<td>Postprandial glycaemic excursion decreased by 43% (p=0.022) after 185mins standing. Energy expenditure 0.83kcal/min (p=0.028) greater in standers. No change in overnight fasting glucose. Standing desk use between 0 and 9h35m. No overall significant change to behaviour.</td>
</tr>
<tr>
<td>Gilson, Suppini, Ryde, Brown, and Brown (2012)</td>
<td>n=11</td>
<td>Single group, repeat measures. 1 week baseline, 1 week intervention</td>
<td>Standing desk (hot desk, voluntary)</td>
<td>46.9 (9.8)</td>
<td>Office staff</td>
<td>Activity - sedentary/light/moderate. Arm band accelerometer.</td>
<td>Workplace daily sitting time reduced by 89mins in multicomponent and 33 mins in workstation only group compared to control</td>
</tr>
<tr>
<td>Neuhaus, Healy, Dunstan, Owen, and Eakin (2014)</td>
<td>n=44</td>
<td>Three-arm quasi-randomised controlled trial. 7 day baseline, 3 month intervention</td>
<td>Sit-stand workstation, Sit-stand workstation with multicomponent education</td>
<td>20-65</td>
<td>University campus (staff)</td>
<td>Accelerometer - time spent in activity</td>
<td></td>
</tr>
<tr>
<td>Reiff et al. (2012)</td>
<td>n=20</td>
<td>Randomised, controlled, crossover</td>
<td>Standing desk (temporary). 45 minutes</td>
<td>22.8 ± 1.9</td>
<td>Laboratory setting</td>
<td>Energy expenditure - oxygen consumed (VO2), carbon dioxide produced (VCO2), and minute ventilation (VE). Producing kcal/min</td>
<td>Significant increase in all participants for VO2, VCO2, VE and Kcal/min.</td>
</tr>
<tr>
<td>Speck and Schmitz (2011)</td>
<td>n=13</td>
<td>Single group, 15 minute baseline, 7 minute intervention</td>
<td>Chair, exercise ball, standing workstation</td>
<td>44.2 (8.5)</td>
<td>Laboratory setting</td>
<td>Energy expenditure - O2 consumption, kcal/min, METs</td>
<td>No significant differences</td>
</tr>
<tr>
<td>Thorp et al. (2013)</td>
<td>n=8</td>
<td>Single group, repeat measures. 1 day baseline, 1 day intervention</td>
<td>Sit-stand workstation. 8 hours - intermittent bouts 30 minutes sitting/standing</td>
<td>48.2 (7.9)</td>
<td>Laboratory setting</td>
<td>Energy expenditure - kJ/day</td>
<td>Significant increase for kJ/day expenditure (89.2 kJ/day)</td>
</tr>
</tbody>
</table>
Chapter 3. Methods
3.1. Study design

The study was designed as a single AB Baseline-Intervention model (Kratochwill et al., 2010) with no repeat phases and was conducted between April and October 2014. The lack of withdrawal and repeat intervention phases are multifactorial, due to the longitudinal nature, logistical complications of furniture supply and ethical implications. The format of the results section follows the guidelines described for single-case designs (Kratochwill et al., 2010) and adaptations to the standard AB model will be described and explained where necessitated.

3.1.1. Phases of experiment

The study was composed of three periods over a total of 21 weeks; 1) baseline (5 weeks), 2) phase-in (3 weeks) and 3) intervention (13 weeks) (see timeline overview in Figure 3.1.1). Participants were scheduled to undergo anthropomorphic and biochemistry sampling every four weeks as well as data export from the Actigraph.

The baseline was comprised of a 5 week period. Participants experienced day to day work-life without any sedentary activity intervention. Anthropometry and biochemistry data collected at the start and completion of this phase with inclinometry data collected at the completion.

The phase-in period commenced in week 6 for a total of 3 weeks. A sit-stand or dedicated standing workstation was installed and participants commenced the phase-in period by transitioning to full-time standing. No data collection points during this phase.

The intervention phase commenced in week 9 and ran for 13 weeks, except where participants withdrew. Participants were instructed to be “mostly” standing by this time with sitting breaks taken at their own discretion. Data collection points occurred at the start of the intervention phase and occurred repeatedly at 4 week intervals until cessation.

3.2. Participant recruitment

Six participants were recruited from the general public using a custom website (Appendix A) as well as coverage from a local newspaper and a national news website (http://www.stuff.co.nz/auckland/local-news/auckland-city-harbour-news/9917147/Benefits-of-working-standing-up-studied). Initial eligibility
was screened using an online questionnaire (Appendix B) and potential participants were then mailed an information sheet (Appendix C) and a consent form (Appendix D) for consideration prior to meeting the primary researcher. Safety information for blood tests (labtests.co.nz/images/Practise_Manual/4.1.10-Safety-Information-For-Patients.pdf) and instructions for fasting tests (labtests.co.nz/images/Practise_Manual/4.1.4-Fasting-tests.pdf) were also provided to participants. Due to the placement of new furniture, participants were required to gain consent from their employers to be included in the study. All participants gave written informed consent and the study was approved by the Unitec Research Ethics Committee (UREC 2013-1029) (Appendix E).

3.2.1. Inclusion criteria

Participants were required to be aged between 25 and 40 years with a self-reported height and weight that resulted in a BMI of between 25 and 30 kg/m². A minimum self-estimated daily occupational sitting time of 5 hours was a requirement with a low expectance of time away from work over the 5 month study period. All participants were required to be registered with a general practitioner in case of the need for referral due to elevated risk of metabolic events.

3.2.2. Exclusion criteria

Potential participants were excluded if they had been previously diagnosed with CVD, any form of diabetes or MetS. Any history of angina or stroke resulted in ineligibility, as well as smoking or current medication that may alter blood pressure, blood glucose, triglycerides or cholesterol concentration or be currently taking weight loss medication or other weight loss programme.

3.2.3. Lifestyle variables

During the study, participants were asked to avoid changes in diet and leisure activity to maintain what they consider to be typical of their six-month average. It was considered outside of the scope of this study to monitor food intake or physical exercise outside of the inclinometer wear-time over the period of participation. As such, participants were not required to maintain a log of any food intake or physical activity. The study was purposefully conducted outside of the New Zealand summer holiday period of December to January to avoid seasonal changes in physical activity associated with leisure activities.

3.3. Equipment

Following a baseline period, participants were supplied with one of two workstation configurations on the basis of availability: a fixed-height workstation and stool, that could be adjusted to suit participant height at installation, of custom design and manufacture (AUT University, Auckland, NZ); or a ‘Sit to stand electric Desk’ (Linak New Zealand Ltd, Auckland, NZ) to be used with the participant’s existing chair. The allocated workstations were installed by the researcher to temporarily replace the participant’s current
seated workstation. The fixed height workstations and stools were adjusted according to the participant’s height upon installation and participants were encouraged to seek assistance from the researcher if they perceived the need for further minor adjustment.

As required for ethical approval of the study, participants were given opportunity to purchase their workstation or a suitable similar workstation, at the conclusion of the intervention period. Workstations were removed at the end of the study where participants did not wish to purchase the supplied furniture.

Participants were supplied with an Actigraph GTX3+ or a wGTX3+ (Actigraph, Pensacola, FL) for the duration of the study to be worn during work hours. The Actigraph was fastened mid-way on the lateral thigh (left or right at participant preference) using a custom made elastic strap and a plastic clip for easy removal. The thigh was selected following pilot tests, which showed greatest accuracy in a variety of sitting and standing postures or when standing with legs crossed over, such as when leaning on furniture. A power-adapter was supplied to charge the device as well as an information sheet for recognising faults (Appendix F). Participants were not asked to record a log of Actigraph wear time.

3.4. Training and support

At the beginning of the phase-in period participants were provided with brief verbal instructions on the use of a standing workstation and recommended posture. A printed information sheet was supplied to participants at the start of the phase-in period to assist with the transition from sitting to regular standing (Appendix G). This included simple mobility exercises intended to ease discomfort and prevent venous pooling from prolonged standing. Additional information or advice was provided as necessary where participants had specific questions about comfort. To allow a progression to comfortable standing, recommendations about daily standing bouts were provided with an end-goal of reducing daily occupational sedentary time by 80%, by increasing standing by 5 to 7 hours per working-day (Table 3.4.1). No requirements were made as to the duration or frequency of standing bouts, only total work-day standing time.

<table>
<thead>
<tr>
<th>Table 3.4.1 – Phase-in period transition to standing recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 1</td>
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<tr>
<td></td>
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<tr>
<td>Week 2</td>
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<td></td>
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<tr>
<td>Week 3</td>
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</tbody>
</table>
3.5. Anthropomorphic, biochemical and physical activity variables

Although the recommendation for 5 data points is suggested as a minimum in single-case design studies, this study was limited to 2 in the baseline and 4 in the intervention phase due to financial and resource limitations.

3.5.1. Anthropometry

Participant height was measured at the commencement of the trial using a 90° angle against a wall and a retractable fibreglass tape measure (NCD Medical Limited, County Dublin, IRL). Weight, waist circumference and blood pressure were measured every four weeks in an appointment at the participant’s workplace. Due to the professional office environment, participants were not required to remove any clothing although it was recommended that lightweight clothing was worn for each appointment.

All measurements during the study were performed by a single trained researcher to reduce inter-rater error. Weight was taken using digital scales (WW185A, Conair Australia Pty Ltd., Belrose, NSW) following the removal of heavy clothing, shoes and belt. Waist circumference was measured over a single layer of clothing (shirt or underwear) using a retractable fibreglass tape measure (NCD Medical Limited, County Dublin, IRL) to the nearest 1cm at the narrowest point between the lowest ribs and the iliac crest (Alberti et al., 2006). Blood pressure was be measured at the left brachial artery while seated, using a sphygmomanometer (Riester Ri-San Palm, Rudolf Riester GmbH, Bruckstr, DE) and stethoscope (Littmann Classic II SE stethoscope, 3M, St. Paul, MN) by averaging 3 measurements with 60s intervals (Wijndaele et al., 2009).

3.5.2. Biochemistry sampling

A total of 6 fasting blood tests were required at 4 week intervals. Biochemistry sampling was performed by phlebotomists at Labtests Ltd (Auckland, NZ) collection centres. Participants were permitted to attend a collection centre of their choice when required. Automated biochemical sample analysis was performed by commercial laboratory (Labtests Ltd) using Siemens Advia 2400 (Siemens Healthcare Diagnostics Inc., Tarrytown, NY). Tests performed were Glucose Hexokinase_3 (GLUH_c) (Siemens Healthcare Diagnostics, 2010), Direct HDL Cholesterol (D-HDL) (Siemens Healthcare Diagnostics, 2008), and Triglycerides (TRIG) (Siemens Healthcare Diagnostics, 2009).

3.5.3. Inclinometry

Actigraph raw data was downloaded from the device at the participant’s location every 4 weeks using proprietary software (Actilife 6.8.2, Actigraph, Pensacola, FL). In the case of loss of charge no new data was collected until the device was recharged and recalibrated at the next collection appointment.
3.6. Statistical Analysis

3.6.1. Anthropometry and biochemistry

Data were analysed using linear regression in Graphpad Prism 6.0 (GraphPad Software, Inc, La Jolla, CA) for the overall study period. Effect sizes (Cohen’s d) were calculated using the means of the first two measurements in the baseline period and the means of the last three measurements (or less due to missing data) in the intervention period. Effect sizes are interpreted using Cohen’s (1988) standard interpretation: 0-0.2 ‘small’, 0.3-0.5 ‘medium’, 0.6-0.8 ‘large’, >0.8 ‘very large’.

Due to the visual nature of data interpretation for single-case design studies (Kratochwill et al., 2010), data points and best-fit trend lines were plotted for each participant. Any changes to dependent variables were considered meaningful if they exceeded the known upper and lower limits of the standard error of measurement; that is, change between the mean must exceed twice the known technical error of measure or biological variation, whichever is larger.

Technical error of measurement for blood glucose concentration was 1.8% (2 mmol/L), 1.3% (4.9 mmol/L) and 1.5% (16.7 mmol/L) (Siemens Healthcare Diagnostics, 2010). Technical error for blood triglyceride concentration was 2.5% (1.32 mmol/L) and 1.5% (2.36 mmol/L) (Siemens Healthcare Diagnostics, 2009). Technical error for blood HDL cholesterol concentration was 2.2% (0.91 mmol/L), 2.1% (1.39 mmol/L) and 2.5% (1.95 mmol/L) (Siemens Healthcare Diagnostics, 2008).

Biological variation for waist circumference was 1.31 cm (World Health Organization, 2011), 10% and 12.6% for systolic and diastolic blood pressure respectively (Mancia et al., 1983). Biochemistry biological variation was 4.8% for blood glucose (Widjaja et al., 1999), 21% triglycerides (Widjaja et al., 1999) and 12.4% for HDL cholesterol (Demacker, Schade, Jansen, & Van ’t Laar, 1982). Note that these figures are likely a combination of the technical error of measurement and true biological variation. No technical error of measurement statistics or biological variation were available for BMI.

3.6.2. Inclinometry

Actigraph device output was captured using Actilife 6.8.2 at a 60s epoch. Data were validated to include only wear time. Actilife output data was calculated into total weekday standing time, stepping time and sitting time (mins) using a custom spreadsheet (Excel, Microsoft Corporation, Redmond, WA) for weekdays of the hours between 8.00 am and 6.00 pm. Activity periods shorter than 60s or continuous periods longer than 120 min were excluded to reduce jitter and non-wear periods respectively. Daily inclinometry data was normalised by activity to a 600 min period using the following method:

\[
\text{total daily normalised activity (mins)} = \left( \frac{\text{total daily activity time (mins)}}{\text{total daily wear time (mins)}} \right) \times 600 \text{ (mins)}
\]
Linear regression was analysed for overall standing, stepping and sitting for each period of the study; baseline, phase-in and intervention. Effect size (Cohen’s d) was calculated using the means of the entire baseline period and the means of the entire intervention period.

3.7. Risk reduction and test results

In case of elevated risk detected during biochemistry sampling or anthropomorphic measures, a letter was sent to the participant’s GP in accordance with the risk levels indicated in the New Zealand Primary Care Handbook 2012 (New Zealand Guidelines Group, 2012) as shown in Table 3.7.1.

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Cardiovascular Risk – participant presents with any of the following</td>
<td></td>
</tr>
<tr>
<td>Obesity BM &gt;30kg/m² or waist circumference &gt;100cm in males or &gt;90cm in females</td>
<td></td>
</tr>
<tr>
<td>Blood Pressure BP ≥ 160/95 mmHg</td>
<td></td>
</tr>
<tr>
<td>Cholesterol Total Cholesterol ≥8mmol/L or TC:HDL ratio ≥7</td>
<td></td>
</tr>
<tr>
<td>Diabetic Risk – participant presents with 2 or more of the following</td>
<td></td>
</tr>
<tr>
<td>Lipids ≥1.7mmol/L, TC ≥4mmol/L</td>
<td></td>
</tr>
<tr>
<td>Blood Pressure BP ≥140/80 mmHg</td>
<td></td>
</tr>
<tr>
<td>Fasting Glucose ≥6.1 mmol/L</td>
<td></td>
</tr>
</tbody>
</table>
Chapter 4. Results
4.1. Participant recruitment

A total of 43 registrations of interest were received with an average age of 35 (SD = 10.05) years. Initial screening excluded 29 people due to age, BMI, history of disease or planned absence of work. Information packs and consent forms were supplied and a further 6 people withdrew their interest. Of the remaining 8 people, 6 were recruited in order of acceptance of place. A flow diagram of the study is shown in Figure 4.1.1 and demographics of participants can be seen in Table 4.1.1.

Figure 4.1.1 – Flow diagram of participant recruitment and enrolment

Table 4.1.1 – Participant demographics at start of study.

<table>
<thead>
<tr>
<th>I.D.</th>
<th>Age (years)</th>
<th>BMI (kg/m²)</th>
<th>Gender</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant A</td>
<td>40</td>
<td>28.7</td>
<td>Male</td>
</tr>
<tr>
<td>Participant B</td>
<td>31</td>
<td>28.3</td>
<td>Female</td>
</tr>
<tr>
<td>Participant C</td>
<td>40</td>
<td>27.2</td>
<td>Female</td>
</tr>
<tr>
<td>Participant D</td>
<td>34</td>
<td>24.1</td>
<td>Male</td>
</tr>
<tr>
<td>Participant E</td>
<td>30</td>
<td>27.3</td>
<td>Female</td>
</tr>
<tr>
<td>Participant F</td>
<td>25</td>
<td>25.4</td>
<td>Female</td>
</tr>
</tbody>
</table>

BMI calculated from self-reported height and weight at time of enrolment.
4.2. Independent results

4.2.1. Participant A

Participant A was male, aged 40 with a self-reported BMI of 28.7 kg/m\(^2\) at recruitment and a measured BMI of 30.84 kg/m\(^2\). Participant A received a fixed-height standing workstation at the commencement of the phase-in period on day 28, which was adjusted for comfort at installation. The intervention period commenced on day 56 and participation was completed on day 149 (108 weekdays). Data are missing for biochemical variables at data point 4 of 6 (day 92). A total of 68 days of Actigraph data were captured. Due to Actigraph device failure, data are missing between days 78 and 108 of the intervention period.

A meaningful decrease with a ‘very large’ effect size \((d = 3.34)\) in waist circumference was noted between baseline \((M = 102.5 \text{ cm}, SD = 2.12)\) and intervention \((M = 97.3 \text{ cm}, SD = 1.15)\) which exceeded the error of measurement (Figure 4.2.1). A ‘very large’ effect \((d = 1.87)\) was also observed for BMI from 30.1 kg/m\(^2\) \((SD = 1.03)\) to 28.7 kg/m\(^2\) \((SD = 0.25)\). A ‘very large’ meaningful effect was also observed in triglycerides \((d = 3.61)\) from baseline \((M = 2.7 \text{ mmol/l}, SD = 0.42)\) to intervention \((M = 1.4 \text{ mmol/l}, SD 0.28)\) (Figure 4.2.1). Changes in systolic blood pressure, diastolic blood pressure, glucose and HDL cholesterol were not meaningful as they did not exceed the error of measurement. No significant regression relationships were detected for anthropometric or biochemical markers.

Following the introduction of the standing workstation daily standing time increased and daily sitting time decreased (Figure 4.2.2). Daily standing time increased from baseline \((M = 88.4 \text{ min}, SD = 35.8)\) to the phase-in period \((M = 148 \text{ min}, SD = 128)\) and increased again in the intervention period \((M = 335 \text{ min}, SD = 100)\). A ‘very large’ effect size \((d = 3.2)\) for the change in daily standing (mins) over time (days) was observed between the baseline and intervention periods, with a significant regression relationship of \((F(1,66) = 38.9, p = .0001)\), with an \(R^2\) of 0.37. The daily standing time remained consistent for the duration of the intervention study, with no significant non-zero regression trend identified.

Daily sitting time also changed from the baseline \((M = 444 \text{ min}, SD = 67.8)\) to phase-in \((M = 273 \text{ min}, SD = 121)\), with further decrease in sitting in the intervention period \((M = 215 \text{ min}, SD = 102)\). A ‘very large’ effect size \((d = 2.64)\) for the decrease in daily sitting (mins) over time (days) was observed, with a regression relationship of \((F(1,66) = 30.9, p = .0001)\), with an \(R^2\) of 0.32. The daily sitting time remained consistent for the duration of the intervention study, with no significant non-zero regression trend found.
Figure 4.2.1 – Participant A anthropometry and biochemistry
A. Between-phase trend of waist circumference and BMI between baseline and intervention
B. Between-phase trend of systole and diastole blood pressure between baseline and intervention
C. Between-phase trend of biochemistry between baseline and intervention
The dotted lines denote commencement of phase-in and intervention periods. Error bars shown where known or visible.
Figure 4.2.2 – Participant A inclinometry
A. Within-phase and between-phase trend of waist circumference and BMI between baseline and intervention
B. Within-phase and between-phase trend of systole and diastole blood pressure between baseline and intervention
The dotted lines denote commencement of phase-in and intervention periods
4.2.2. Participant B

Participant B was female, aged 31 with a self-reported BMI of 28.3 kg/m$^2$ at recruitment and a measured BMI of 28.6 kg/m$^2$. Participant B received a fixed-height standing workstation at the commencement of the phase-in period on day 29, which was adjusted for comfort at installation. The intervention period commenced on day 57 and participation was completed on day 150 (109 weekdays). No data are missing for anthropometric or biochemical variables. A total of 86 days of Actigraph data were captured with no device failure occurring.

A meaningful decrease with a 'very large' effect size ($d = 5.21$) in waist circumference was noted between baseline ($M = 88$ cm, $SD = 1.41$) and intervention ($M = 81.3$ cm, $SD = 1.15$) which exceeded the error of measurement (Figure 4.2.3). A 'very large’ effect ($d = 2.94$) was also observed for BMI from 28.6 kg/m$^2$ ($SD = 0.03$) to 28.2 kg/m$^2$ ($SD = 0.19$). Changes in systolic blood pressure, diastolic blood pressure, glucose, triglycerides and HDL cholesterol were not meaningful as they did not exceed the error of measurement. No significant regression relationships were detected for anthropometric or biochemical markers.

Following the introduction of the standing workstation daily standing time increased and daily sitting time decreased (Figure 4.2.4). Daily standing time increased from baseline ($M = 113$ min, $SD = 56.4$) to the phase in period ($M = 251$ min, $SD = 64.1$) and increased again in the intervention period ($M = 280$ min, $SD = 75.8$). A 'very large' effect size ($d = 2.5$) for the change in daily standing (mins) over time (days) was observed between the baseline and intervention periods, with a significant regression relationship of ($F(1,84) = 22.9, p = .0001$), with an $R^2$ of 0.21. The daily standing time remained consistent for the duration of the intervention study, with no significant non-zero regression trend found.

Daily sitting time also changed from the baseline ($M = 455$ min, $SD = 59$) to phase-in ($M = 320$ min, $SD = 73.6$), with further decrease in sitting in the intervention period ($M = 295$ min, $SD = 67.5$). A 'very large' effect size ($d = 2.52$) for the decrease in daily sitting (mins) over time (days) was observed, with a regression relationship of ($F(1,84) = 25.1, p = .0001$), with an $R^2$ of 0.23. The daily sitting time remained consistent for the duration of the intervention study, with no significant non-zero regression trend found.
Figure 4.2.3 – Participant B anthropometry and biochemistry
A. Between-phase trend of waist circumference and BMI between baseline and intervention
B. Between-phase trend of systole and diastole blood pressure between baseline and intervention
C. Between-phase trend of biochemistry between baseline and intervention
The dotted lines denote commencement of phase-in and intervention periods. Error bars shown where known or visible
Figure 4.2.4 – Participant B inclinometry
A. Within-phase and between-phase trend of daily standing time (mins) between baseline and intervention
B. Within-phase and between-phase trend of daily sitting time (mins) between baseline and intervention
The dotted lines denote commencement of phase-in and intervention periods
4.2.3. Participant C

Participant C was female, aged 40 with a self-reported BMI of 27.2 kg/m² at the start of the study. Participant C received an electric sit-stand desk at the commencement of the phase-in period on day 38, the intervention period commenced on day 66 and participation was completed on day 172 (125 weekdays). Data are missing for anthropometric variables at data point 4 of 6 (day 101) and biochemical variables at data point 3 (day 73) and data point 4 (day 101). A total of 73 days of Actigraph data were captured. Due to Actigraph device failure, inclinometry data are missing between days 78 and 121 of the intervention period. At the completion of the study the participant purchased the sit-stand workstation.

A meaningful decrease with a 'very large' effect size \( (d = 2.24) \) in waist circumference was noted between baseline \( (M = 77.5 \text{ cm}, \ SD = 0.71) \) and intervention \( (M = 75 \text{ cm}, \ SD = 1.41) \) which exceeded the error of measurement (Figure 4.2.5). A 'very large' effect \( (d = 2.94) \) was also observed for the increase of BMI from 25 kg/m² \( (SD = 0.24) \) to 25.5 kg/m² \( (SD = 0.06) \). Changes in systolic blood pressure, diastolic blood pressure, glucose, triglycerides and HDL cholesterol were not meaningful as they did not exceed the error of measurement. No significant regression relationships were detected for anthropometric or biochemical markers.

Following the introduction of the standing workstation daily standing time increased and daily sitting time decreased (Figure 4.2.6). Daily standing time increased from baseline \( (M = 187 \text{ min}, \ SD = 78.9) \) to the phase in period \( (M = 260 \text{ min}, \ SD = 77) \) and increased again in the intervention period \( (M = 298 \text{ min}, \ SD = 96.3) \). A 'very large' effect size \( (d = 1.26) \) for the change in daily standing (mins) over time (days) was observed between the baseline and intervention periods, with a significant regression relationship of \( (F(1,71) = 20, \ p = .0001) \), with an \( R^2 \) of 0.22. The daily standing time remained consistent for the duration of the intervention study, with no significant non-zero regression trend found.

Daily sitting time also changed from the baseline \( (M = 381 \text{ min}, \ SD = 93.6) \) to phase-in \( (M = 313 \text{ min}, \ SD = 83.1) \), with further decrease in sitting in the intervention period \( (M = 269 \text{ min}, \ SD = 90.1) \). A 'very large' effect size \( (d = 1.22) \) for the decrease in daily sitting (mins) over time (days) was observed, with a regression relationship of \( (F(1,71) = 21, \ p = .0001) \), with an \( R^2 \) of 0.23. During the intervention period there was a significant negative trend towards decreased daily standing time \( (F(1,27) = 6, \ p = .02) \), with an \( R^2 \) of 0.18. During the intervention period there was a significant negative trend towards decreased daily standing time \( (F(1,27) = 6, \ p = .002) \), with an \( R^2 \) of 0.18.
Figure 4.2.5 – Participant C anthropometry and biochemistry
A. Between-phase trend of waist circumference and BMI between baseline and intervention
B. Between-phase trend of systole and diastole blood pressure between baseline and intervention
C. Between-phase trend of biochemistry between baseline and intervention
The dotted lines denote commencement of phase-in and intervention periods. Error bars shown where known or visible.
Figure 4.2.6 – Participant C inclinometry

A. Within-phase and between-phase trend of daily standing time (mins) between baseline and intervention

B. Within-phase and between-phase trend of daily sitting time (mins) between baseline and intervention

The dotted lines denote commencement of phase-in and intervention periods
4.2.4. **Participant D**

Participant D was male, aged 34 with a self-reported BMI of 24.1 kg/m² at recruitment and a measured BMI of 24.6 kg/m². Participant D received an electric sit-stand workstation at the commencement of the phase-in period on day 27, which was adjusted for comfort at installation. The intervention period commenced on day 55 and the participant withdrew on day 90 (65 weekdays) due to geographical relocation. No data are missing for anthropometric or biochemical variables during participation; however, due to withdrawal only 1 data point is available in the intervention period. A total of 44 days of Actigraph data were captured, with missing data 75 and 80 of the intervention period. At the completion of the study the participant purchased the sit-stand workstation.

A meaningful increase with a 'very large' effect size ($d = 1.67$) in blood glucose was noted between baseline ($M = 5.15$ mmol/L, $SD = 0.64$) and intervention ($M = 5.9$ mmol/L, $SD = 0$) which exceeded the error of measurement (Figure 4.2.7). Changes in waist circumference, BMI, systolic blood pressure, diastolic blood pressure, triglycerides and HDL cholesterol were not meaningful as they did not exceed the error of measurement. No significant regression relationships were detected for anthropometric or biochemical markers.

Following the introduction of the standing workstation daily standing time increased and daily sitting time decreased (Figure 4.2.8). Daily standing time increased from baseline ($M = 147$ min, $SD = 118$) to the phase in period ($M = 190$ min, $SD = 58.6$) and increased again in the intervention period ($M = 267$ min, $SD = 77.9$). A 'very large' effect size ($d = 1.20$) for the change in daily standing (mins) over time (days) was observed between the baseline and intervention periods, with a significant regression relationship of ($F(1,42) = 8.98, p = .0046$), with an $R^2$ of 0.18. The daily standing time remained consistent for the duration of the intervention study, with no significant non-zero regression trend found.

Daily sitting time also changed from the baseline ($M = 395$ min, $SD = 124$) to phase-in ($M = 359$ min, $SD = 73.4$), with further decrease in sitting in the intervention period ($M = 288$ min, $SD = 79.2$). A 'very large' effect size ($d = 1.03$) for the decrease in daily sitting (mins) over time (days) was observed, with a regression relationship of ($F(1,42) = 4.81, p = .034$), with an $R^2$ of 0.1. The daily sitting time remained consistent for the duration of the intervention study, with no significant non-zero regression trend found.
Figure 4.2.7 – Participant D anthropometry and biochemistry.
A. Between-phase trend of waist circumference and BMI between baseline and intervention
B. Between-phase trend of systole and diastole blood pressure between baseline and intervention
C. Between-phase trend of biochemistry between baseline and intervention
The dotted lines denote commencement of phase-in and intervention periods. Error bars shown where known or visible.
Figure 4.2.8 – Participant D inclinometry.

A. Within-phase and between-phase trend of daily standing time (mins) between baseline and intervention
B. Within-phase and between-phase trend of daily sitting time (mins) between baseline and intervention

The dotted lines denote commencement of phase-in and intervention periods.
4.2.5. **Participant E**

Participant E was female, aged 30 with a self-reported BMI of 27.3 kg/m² at recruitment and a measured BMI of 32.71 kg/m². Participant E received an electric sit-stand workstation at the commencement of the phase-in period on day 39, which was adjusted for comfort at installation. The intervention period commenced on day 69 and participation was completed on day 164 (119 weekdays). Anthropometry data are missing for data point 5 of 6 (day 149) and biochemical data are missing for data point 3 (day 81) and data point 5 (day 149). The final biochemical data collection was taken at day 207, 43 days after completion. Due to a fault no Actigraph data are available for the entire period of the study. At the completion of the study the participant purchased the sit-stand workstation.

No meaningful changes were detected for waist circumference, BMI, systolic blood pressure, diastolic blood pressure, glucose, triglycerides and HDL cholesterol as they did not exceed the error of measurement. No significant regression relationships were detected for anthropometric or biochemical markers.
**Figure 4.2.9** – Participant E anthropometry and biochemistry.

A. Inter-phase trend of waist circumference and BMI between baseline and intervention

B. Inter-phase trend of systole and diastole blood pressure between baseline and intervention

C. Inter-phase trend of biochemistry between baseline and intervention

The dotted lines denote commencement of phase-in and intervention periods. Error bars shown where known or visible.
4.2.6. Participant F

Participant F was female, aged 25 with a self-reported BMI of 25.4 kg/m\(^2\) at recruitment and a measured BMI of 27.2 kg/m\(^2\). Participant F received an electric sit-stand workstation at the commencement of the phase-in period on day 37, which was adjusted for comfort at installation. The intervention period commenced on day 65 and the participant withdrew on day 129 (94 weekdays) due to geographical relocation. No data are missing for anthropometric or biochemical variables during participation; however, due to withdrawal only 1 data point is available in the intervention period. A total of 75 days of Actigraph data were captured, with no device failure.

An increase with a ‘very large’ effect size (\(d = 4.83\)) in BMI was noted between baseline (\(M = 27\) kg/m\(^2\), \(SD = 0.24\)) and intervention (\(M = 28.4\) kg/m\(^2\), \(SD = 0.33\)) (Figure 4.2.10). Changes in waist circumference, systolic blood pressure, diastolic blood pressure, blood glucose, triglycerides and HDL cholesterol were not meaningful as they did not exceed the error of measurement. No significant regression relationships were detected for anthropometric or biochemical markers.

Following the introduction of the standing workstation daily standing time increased and daily sitting time decreased (Figure 4.2.11). Daily standing time increased from baseline (\(M = 99.8\) min, \(SD = 67.6\)) to the phase in period (\(M = 224\) min, \(SD = 103\)) and increased again in the intervention period (\(M = 441\) min, \(SD = 72\)). A ‘very large’ effect size (\(d = 4.45\)) for the change in daily standing (mins) over time (days) was observed between the baseline and intervention periods, with a significant regression relationship of \((F(1,73) = 183, p = .0001)\), with an \(R^2\) of 0.72. During the intervention period there was a significant positive trend towards increasing daily standing time \((F(1,37) = 6.83, p = .0129)\), with an \(R^2\) of 0.15.

Daily sitting time also changed from the baseline (\(M = 487\) min, \(SD = 68.4\)) to phase-in (\(M = 363\) min, \(SD = 108\)), with further decrease in sitting in the intervention period (\(M = 176\) min, \(SD = 68.8\)). A ‘very large’ effect size (\(d = 4.53\)) for the decrease in daily sitting (mins) over time (days) was observed, with a regression relationship of \((F(1,73) = 185, p = .034)\), with an \(R^2\) of 0.72. During the intervention period there was a significant negative trend towards decreased daily standing time \((F(1,37) = 8.95, p = .0049)\), with an \(R^2\) of 0.19.
A

Figure 4.2.10 – Participant F anthropometry and biochemistry.
A. Between-phase trend of waist circumference and BMI between baseline and intervention
B. Between-phase trend of systole and diastole blood pressure between baseline and intervention
C. Between-phase trend of biochemistry between baseline and intervention
The dotted lines denote commencement of phase-in and intervention periods. Error bars shown where known or visible.

Day number

Day

Concentration (mmol/L)

Diastole
Systole

Blood pressure (mm Hg)

0
50
100

0
50
100

0
50
100

Glucose
Triacylglycerol
HDL Cholesterol
**Figure 4.2.11** – Participant F inclinometry.

A. Within-phase and between-phase trend of daily standing time (mins) between baseline and intervention

B. Within-phase and between-phase trend of daily sitting time (mins) between baseline and intervention

The dotted lines denote commencement of phase-in and intervention periods.
Chapter 5. Discussion
5.1. Findings

The aims of this study were to assess the impact of using standing workstations to reduce occupational sitting time and measure any potential changes in the markers of MetS. Six office workers participated for a total of 620 weekdays, over which time a total of 31 anthropometric and 27 biochemical data points were collected. A total of 346 weekdays of occupational inclinometry data were collected across 5 participants, with device failure resulting in no inclinometry data being available for 1 participant.

Following the introduction of a sit-stand or standing workstation, changes were seen for objectively measured daily occupational standing time and sitting time for 5 participants between the baseline and intervention periods. The minimum increase in daily standing was 111 min/day and the maximum increase in daily standing was 341 min/day. The minimum decrease in daily occupational sitting was 107 min/day and the maximum was 311 min/day. These reductions in daily sitting and increases in daily standing were maintained during the entire intervention period by all participants. Even where participants had the option to sit down, either on the provided stools or, where available, by lowering their electric height-adjustable desk, participants still chose to stand for long periods of time.

Changes were observed for some markers of MetS in some participants. A meaningful decrease that exceeded measurement error was observed for waist circumference in three participants between the baseline and intervention periods. The smallest change was a decrease in waist circumference of 2.5 cm and the largest change was a decrease of 6.7 cm. Change was also seen for BMI with two participants experiencing a decrease and two participants experiencing an increase. Finally, some changes in biochemical markers were seen, with one participant experiencing a decrease in blood triglyceride concentration of 1.3 mmol/L between baseline and intervention. An increase in blood glucose concentration was seen in one participant of 0.75 mmol/L between baseline and intervention.

The failure to detect meaningful change in the metabolic markers for the participants might be explained by the complex processes involved in the development MetS, as well as the limitations of this study. While an increase in standing time may produce higher energy expenditure, it may be that the 13 week intervention duration of this study was not long enough to capture a change exceeding the natural variation. As this study did not monitor or adjust for physical activity or diet, it may be that these influences negated any beneficial impact experienced through a reduction of sedentary behaviour. MetS development is likely comprised of a number of environmental changes including quantity and nutritional content of food selection and a decrease of light, moderate and
vigorous intensity physical activity. It is possible that the use of standing desks may be complimentary to a larger environmental intervention program that incorporates dietary and physical activity modification. Nonetheless, it may be that with an extended intervention period and control or statistical modelling to adjust for food and exercise, changes to MetS markers may become more apparent.

Attempts were made to provide some control through recommendations to maintain diet and exercise. While this may have produced mild reduction to the effects of external variables, such as participants engaging in new sports, it potentially increases risk for participants. A recommendation to maintain a 6 month average dietary intake and level of physical activity may produce a barrier to health for participants who have an excuse to avoid lifestyle interventions. Instead, it is suggested that future studies attempt to monitor for diet, moderate and vigorous physical activity as well as leisure time sedentary behaviour in order to produce adjusted models for statistical analysis that might provide far more accurate appraisal of any changes.

The increase in daily standing and decrease in daily sitting may have been attributable to the ‘novelty’ of the new equipment, as well as a desire to succeed under observation. This might have been reinforced if participants returned to their baseline sitting and standing levels as the novelty of the intervention dissipated. Where results were available from Actigraph data, all participants displayed a consistent stability in the intervention period standing and sitting times, with one participant showing a significant regression trend towards continuing increases in daily standing and two participants showing a significant trend towards further decreases in sitting time. This stability towards decreased sedentary behaviour is encouraging; however, these results cannot be generalised for long periods and longer term changes may be different to that observed in this study.

Changes in sedentary behaviour observed during the study reflect the findings of similar studies. Alkhajah et al. (2012) showed that the use of a sit-stand workstation in office workers (n=32) decreased occupational sitting by 143 min/day (95% CI = -184 to -102) with participants maintaining reductions in sitting and increases in standing after 3 months. Similarly changes in sedentary behaviour were also seen by Neuhaus et al. (2014) where participants in standing workstation groups decreased their total daily sitting time by between 33 and 89 min/day.

The lack of metabolic change is also reflected in similar studies. While Buckley et al. (2014) showed that postprandial blood glucose levels were lower following periods of standing, they failed to observe a significant decrease in overnight blood glucose levels between sitting and standing participants. Equally, Alkhajah et al. (2012) saw an increase in HDL cholesterol following the
introduction of a standing workstation; however, no changes were observed for blood glucose or triglycerides following a 3 month intervention period. While there is evidence in these studies that metabolic changes can occur through the use of a standing workstation, as seen in decreased postprandial blood glucose and increased HDL cholesterol, it may be that the intervention period was too short to observe long term change.

The outcomes of this study provide preliminary and low-level evidence that the use of a sit-stand or standing workstation can reduce occupational sedentary behaviour and increase occupational standing time. Sedentary behaviour is associated with detrimental changes to the markers of MetS (Healy, Wijndaele, et al., 2008) as well as an increased risk for CVD and all-cause mortality (Stamatakis et al., 2011) that is independent of physical activity levels. Therefore, concern for the welfare of office based workers may be addressed by reducing sedentary behaviour through replacement with light-intensity physical activity, such as standing (Healy et al., 2007).

5.2. Limitations of this study

Some limitations were experienced that may have affected the outcome variables. Many of the markers of MetS are subject to natural variability over short and long periods of time. Blood pressure is dynamic and modulated by daily occupational stress, coffee and stimulant intake or simply through the process of measurement (Parati, Ochoa, Lombardi, & Bilo, 2013). Natural variation of blood pressure (Parati et al., 2013), biochemical markers (Demacker et al., 1982; Widjaja et al., 1999), weight and even height (Lohmann, Roche, & Martorell, 1988) has been well documented. Analysis included natural errors where known, so that only changes exceeding these natural variations were considered to be meaningful. However, it is likely that although not visible in the results, variations of individual markers that did not exceed the measurement error have influenced any anthropomorphic or biochemical changes in participants during this study.

Additionally, some changes may occur through seasonal variation in diet or changes to physical activity, which may not have been captured accurately due to the short time-frame of this study. Due to the exploratory nature of this pilot study, participants were not required to maintain physical activity or food diaries which may be useful in subsequent studies. While this study avoided the New Zealand summer holiday period, it may be that the effects of of several weeks of altered behaviour may produce long lasting results. Equally, as this study occurred across autumn and winter months, there may have been changes to dietary patterns as a result of colder weather and shorter daylight hours.

A major contributing factor in the limitations of this study were the financial and time costs associated with regular sampling and laboratory charges. Difficulties with participant scheduling
due to work constraints meant that in many cases sampling of anthropometric markers was delayed or occurred at sub-optimal periods. The delays of data collection may have been mitigated by collecting anthropometric data alongside biochemical data following a period of fasting.

There were repeated failures in Actigraph inclinometry data due to battery depletion and device failure. Due to the 4 week interval between downloads, any device failure that occurred during this time was not identifiable until the next collection point. Battery depletion occurred in three devices resulting in 74 days of missing data. Although battery chargers and instruction sheets were provided to participants, the LED indicator on the device was regularly concealed under clothing and might have been difficult to notice. One Actigraph was faulty, resulting in up to 119 days of unusable data which was only realised at the end of the study. These errors could have been avoided with improved participant training so that a low battery fault could be rectified before device shut-down. Additionally, more vigorous device testing prior to study and frequent integrity checks of captured data may have identified the faulty device earlier. Data monitoring in field-based studies is desirable to ensure good quality data and minimisation of missing data points; however, monitoring also involves investigator time and cost that were beyond the scope of the current study.

5.3. Recommendations for future studies

The results of this study provide sufficient evidence to justify future research that examine the effects of sit-stand or standing workstations on the levels of sedentary behaviour in sedentary office workers. Further, there is enough supporting evidence to suggest that although only small changes were seen in the MetS markers, a sound basis of research supports the idea that decreasing sedentary behaviour may provide a positive impact on metabolic health.

Recommendations for future research include changes to study design, size, duration and data analysis. A large sample randomised-controlled study, over a longer period of time, would allow for selection of participants across a wider range of demographics and health status. A larger sample would also allow for a greater comparison between the results of a sit-stand intervention group and a sitting only group. During the course of this study it was learned through anecdotal sources that several Auckland based companies undertook office retrofits and introduced sit-stand workstations on a company-wide basis. A research study integrating with an office retrofit may provide an economically efficient opportunity for investigators by reducing study expenses as well as gaining access to a larger sample.

An increased number of breaks in sedentary time, such as standing up for at least 1 minute, may be associated with improved blood glucose, waist circumference and HDL cholesterol (Healy, Dunstan, et al., 2008). Future studies should investigate the patterns of sedentary and standing
time as a result of the implementation of standing desks. The use of accelerometers and inclinometers provides for in depth analysis of occupational sedentary behaviour patterns. Through the use of a larger sample, future research may also provide a cross-sectional analysis of the New Zealand sedentary behaviour profile, such as occupational sitting time, average time spent sitting or standing or the change in behaviour throughout the day and week. This information may allow aid in education programs or to develop intervention strategies.

Future researcher may choose to investigate non traditional markers of metabolic syndrome in addition to those classified under WHO, ATPIII, EGIR or criteria decribed by the International Diabetes Federation. For example, an investigation examining changes found in LDL particle size, systemic pro-inflammatory markers such as C-reactive protein, adipocyte macrophage population or lipoprotein lipase activity may discover important changes following the reduction of sedentary behaviour. As the metabolic syndrome is poorly understood, research of this nature may assist the international community to better understand how sedentary behaviour impacts the wide array of metabolic disturbances that occur in people experiencing MetS, T2DM and CVD.

Learnings from field-notes made during this study may also assist future researchers. Efficient organisation and planning of data collection points may help to reduce missed appointments with participants. Additionally, the use of a central data collection point, such as a laboratory, where participants can be assessed may reduce the time costs associated with data collectors visiting individual participants. Additionally, visits to participants may help to ensure that anthropometric or biochemical data are all captured at optimal times, such as first thing in the morning before breakfast or caffeine intake. Researchers may find that regular checks of inclinometer or accelerometer devices and captured data will reduce the likelihood of lost data. Where possible, replacement of participant furniture might be done by the manufacturing and supplying company at the time of delivery, in order to minimise delay and reduce researcher demands.
Chapter 6. References


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Chapter 7. Appendices
Appendix A. Recruitment website
Take a seat

Half of us sit. About half of us are sitting between three and six hours per day and nearly a third of us sit for more than six hours per day. Our modern lifestyles seem to encourage sitting for hours at a time. Even if you add up the daily commute, a day spent in the office and an exhaustive evening spent on the couch it is easy to understand how much time is being spent in a physically inactive state.

Many local health initiatives focus on reducing inactivity, during our daily commute or outside of the workplace. While these campaigns are important and often successful, they don’t address a huge down by sedentary behaviour for many office workers, that is reducing the time we spend sitting at desks during working hours.

The rest of the world isn’t having much success in reducing workplace sitting. A review of all available research around the world and in multiple languages showed that only a handful of studies tried to directly influence the time we spent sitting at work. Of the seven campaigns found to attempt to influence office sitting time by the review, none showed any actual reduction of sitting time in office workers.

The health risks


Is sitting making us sick?

New research suggests that sitting for as little as two hours per day can have negative effects on health. It appears now that those who sit for long periods of time, especially when that sitting time is unbroken, may be at greater risk of developing metabolic syndrome. Metabolic syndrome is defined when a person has high levels of blood sugar, blood fats and cholesterol, increased weight and small waist circumference.

Metabolic syndrome is considered a precursor to stroke, type 2 diabetes, cardiovascular disease, and is a contributing factor in many other diseases. In a long-term study comparing average daily sitting time against hospital admissions, it was discovered that people who sat for greater than two hours a day had significantly higher occurrences of type II diabetes, cardiovascular disease, obesity and other diseases than people who sat for less than two hours a day. Importantly, it now appears that these negative effects from sitting are not reversed by exercise.

Stand up desks are fast becoming popular amongst those who are tired of sitting. Many New Zealand companies are setting up standing hot desks for employees to use. This study aims to take this idea one step further by replacing the desk entirely and reducing the time spent sitting at work so that we can investigate whether some of the risk factors of metabolic syndrome are changed or even reduced through the reduction of sedentary behaviour.

Making a change

We want to try something new

This longitudinal study aims to equip Auckland-based, desk-based office workers with the ability to change their sedentary behavior. During the course of the study we will be monitoring the change in your sitting habits as well as some health markers that are classically described when assessing metabolic syndrome.

Using a small actigraph movement monitor we will collect information about how much time you spend sitting and standing during the day. For the first few weeks you will have to do nothing different to your normal daily routine while we get a baseline measurement of your daily sitting patterns. In the sixth week we will provide you with a standing desk in your workplace as long as it’s approved by your employer to give you a few weeks to ease yourself into spending the day standing. From week nine we will ask you to spend as much time as possible standing at your desk.

In order for us to assess the possible change in the markers of your health we will ask you to take some simple tests every four weeks. These will include your weight, waist circumference and giving blood to allow us to measure your blood sugar, cholesterol and blood fats. Blood testing will be done at a qualified laboratory under sterile conditions, and if there are any concerns we will send you to your doctor for a check-up.

During the 21-week study we will also ask you to complete short, regular and simple health questionnaires so we can gain a better understanding of how standing up at work is affecting you. To learn more about your experiences we would also like to conduct three face-to-face interviews, one before you start standing at work, one just before you finish, and one just after you finish standing. The interviews and questionnaires will help us gain insight into your experiences using a standing desk, which will help us deal any issues to be solved with future studies.

We are looking for Auckland based office workers who sit for 6 or more hours per day as part of their job. You should be aged between 25 and 45, and have no history of cardiovascular disease, diabetes, stroke or episodes of chest pain or angina. Additionally, we are looking for non-smokers who are not taking any medication that alters blood pressure, cholesterol, blood sugars or fats, or weight loss medication.

If you are interested in finding out more then view our fact sheet below or contact us with your questions.

download a fact sheet

contact us
Contact us

If you are interested in finding out more about our trial please get in touch with us below!

Your name (required): 

Your Email (required): 

Your Message: 

7918

Please enter the characters you see above:

Send

UREC REGISTRATION NUMBER: 2013/1029

This study has been approved by the UNEEC Research Ethics Committee from 02 September 2013 to 15 August 2014. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the UREC Secretary (ph: 06 810-4321 ext 8161). Any issues you raise will be treated with confidence and investigated fully, and you will be informed of the outcome.
Appendix B. Online eligibility questionnaire
The Standing Study Questionnaire

A little about your health

We would like you to take part in the study and to answer these questions carefully.

During your participation you will need to be registered with a doctor. Are you currently registered with a GP?

- Yes, I'm registered with a GP
- No, I am not registered with a GP

Have you ever been diagnosed with any of the following?

Select as many or few as relevant.

- Diabetes
- Cardiovascular disease
- Hypertension
- Stroke
- Sleep-related disorders

Do you smoke?

- Yes, I am a smoker
- No, I do not smoke

[Input field for date]

[Continue button]

60% completed

The Standing Study Questionnaire

Some questions about the tests

To be part of this study, we will ask you to undergo some tests, testing once a month.

All results are strictly confidential. The only people with access to the test results will be the researchers, yourself, and your GP.

Are you comfortable having a small device attached to the outside of your thigh to measure your movements?

- Yes, I'm happy to wear a movement monitor
- No, I'd prefer not to

Can we visit you monthly to download the data from your movement monitor?

- Yes, you can visit monthly to download data
- No, I'd prefer you didn't

Are you willing to have regular blood tests to measure blood sugar, lipids, insulin?

You will need to have your blood taken once per month. This test will be done before your morning meal, and will be done at a laboratory service convenient to you.

- Yes, I'm happy to have monthly blood tests
- No, I'd prefer not to

Will you consent to us taking your weight, waist circumference and blood pressure?

We will do this once a month.

- Yes, I consent
- No, I'd prefer you didn't

[Input field for date]

[Continue button]

60% completed
The Standing Study Questionnaire

Your feedback about your experience

As a part of your participation we would like to ask you about your experience of using a standing desk.

Will you be willing to complete a questionnaire every fortnight?
- Yes, I’m happy to complete a fortnightly questionnaire
- No, I’d prefer not to

Are you willing to participate in three interviews during the study?
- Yes, I’m happy to complete a series of interviews
- No, I’d prefer not to

Submit

Thank you.

© 2013 the Standing Desk
Appendix C. Information sheet for participants

Information for participants

A standing desk intervention on the markers of metabolic syndrome in sedentary office workers
&
Participant experience and acceptability of using a standing desk in a workplace environment

What are these projects about?

In today’s modern world people are becoming less physically active in their daily lives. Sedentary behavior can occur in three major phases of our daily lives: during our commute to work, at work, and in our personal leisure time.

Recent research shows us that people who are sedentary for large portions of their day have elevated risks of developing conditions such as type II diabetes and cardiovascular disease. Worryingly, the same research suggests that these risks may not be reduced by exercise; instead the risks have stronger links to how much we rest during the day.

What we are doing?

The first project aims to reduce the amount of time spent sedentary in the office by asking our participants to use special stand-up desks during their office hours.

The second project aims to ascertain the experience of participants in the standing desk intervention. The study aims to identify and understand perceptual and subjective factors pertaining to the acceptability of adapting to, and working from, a standing desk.

What will I be required to do?

Your participation in this research will mean a slight change in the way you work. We will provide you with a stand-up desk in your workplace for the duration of this study. Instead of sitting for the day, we will ask you to stand up instead. We will also equip you with an ‘actigraph’ to wear on your thigh which will allow us to measure how much you are standing during your day. The data from this will be collected once per month. At the end of the study you will be required to return the stand-up desk as well as the thigh-worn accelerometer. If after participating in the study you are interested in permanently changing to a stand-up desk, we will supply you with the details of local suppliers.

Every four weeks over the course of the study we will ask you to undergo some simple tests. These include your weight, your waist measurements, your blood pressure, your fasting blood sugar, blood cholesterol, and lipid levels. These tests will be performed ‘free of change’. Because these blood tests are ‘fasting’ tests, we will ask you to have them done before you eat breakfast or any food, on a day of your choice, at a laboratory location of your choice. There will be a total of six tests. We won’t test for anything else and the only people who will see these results will be the researchers, yourself, and your doctor if we or you believe it is necessary.

There will also be fortnightly questionnaires on health-related issues. There are two questionnaires that will take approximately 10-15 minutes each to complete. These can be
completed online or on paper for your convenience. In addition it is asked that you participate in three interviews these will be no longer than an hour. These will happen one week after you start using the standing desk, one week before you stop using the desk, and one week after you stop using the desk. The audio from these interviews will be recorded, analysed, and used as data for the research report. These interviews and questionnaires will help us gain insight into your experiences using a standing desk which will help reveal any issues to be solved with future research.

You will be given a diary in which you can also record your experiences or note as you think of them. This does not require regular entries. These will be handed in at the last interview. This is optional extra if you wish to.

What risks are there in taking blood samples?
Having your blood taken may carry some risks. These risks include some bleeding at the site of the needle, fainting or light-headedness, blood accumulation under the skin or the possibility of a mild infection. Labtests uses only single-use sterile equipment to reduce any risks. Only trained and experienced phlebotomists can take blood in conditions designed to reduce infection.

What are some of the difficulties in standing more than usual?
Due to the nature of this project you may find yourself getting fatigued or uncomfortable during standing, especially in the early stages while you adapt. For the first 3 weeks after receiving the stand-up desk you will slowly phase in your standing time until you are able to comfortably stand for at least 6.5 hours in your working day. To reduce discomfort it is recommended that you wear good quality and comfortable shoes to work. The researchers will also provide a number of exercises, stretches and strategies to stay comfortable during the day. We will also keep in regular contact to support and guide you and help you stay happy on your feet.

If something goes wrong how am I covered for injury?
In the rare chance that you experience an injury as a result of your participation you will be covered by ACC. ACC covers workplace injuries for New Zealand citizens and permanent residents, including those that may occur as a result of this study. To be eligible for this study you will need to provide evidence of your permanent residence or citizenship and allow us to make a copy for our records.

Will my GP need to be involved in this study?
In order to be eligible to participate in this study, we require you to be enrolled with a General Practitioner for the duration of this study. You will be free to discuss any aspect of this study with your GP, as well as any of the test results. You will not be eligible to participate if you have any history of cardiovascular disease or heart problems, if you have a history of diabetes, stroke or deep vein thrombosis, or if you are taking any drugs to control your cholesterol, blood lipids or blood pressure. If the researchers or Labtests feel that your test results are concerning, your results will be automatically forwarded to your GP and we will recommend you schedule an appointment to see them.

Who will have access to my personal information?
All information collected from you will be stored on a password protected file and only you, the principal researcher and supervisors will have access to this information. Your name and any information that may identify you will be kept completely confidential. 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 at any time.
Who should I contact for more 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 us.

Thank you for taking the time to consider being a part of our research

info@thestandingsudy.co.nz

Dan Archer, 021 874913 or email: dan@thestandingsudy.co.nz
Sheehan Robb, 021 0403042 or email: sheehan18@hotmail.com
Robert Moran, 815 4321 ext 8197 or 021 0739984 or email: rmoran@unitec.ac.nz

UREC REGISTRATION NUMBER: 2013-1029
This study has been approved by the UNITEC Research Ethics Committee from 02 September 2013 to 15 August 2014. 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. Consent Form

Participant Consent Form

A standing desk intervention on the markers of metabolic syndrome in sedentary office workers & Participant experience and acceptability of using a standing desk in a work place environment

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

I understand that this 21 week project will occur in two phases. In the first five weeks I will sit at my regular desk after which point I will be supplied with a special stand-up desk and raised seating. For the remaining 16 weeks I will be asked to stand as much as possible while performing my normal daily tasks at work, and will be able to sit for a total of three 30 minute periods if I wish to. I also understand that I will be asked to wear a small device on my thigh for the entire day, every week day, which will measure how much movement I am doing.

I consent to undergoing periodic testing every four weeks during this project totalling six tests. In these tests my height, weight, and waist circumference will be taken.

I understand that at each of the test points I will consent to providing a blood sample at a Labtests collection centre of my choice. I know that this will test for fasting blood glucose (sugar) and blood lipids (cholesterol and fats), which means the test will be taken first thing in the morning before I have eaten breakfast. I have been informed that absolutely no other substances or chemicals will be tested during the entire project. I understand that all blood samples will be destroyed.

I hereby confirm that I am registered with a general practitioner and will remain registered for the duration of this project. I am free to provide any of the test results to them at any point. I acknowledge that should any of my tests warrant further investigation they will be forwarded to my doctor by Labtests automatically. I also understand that should the researchers feel concerned with my participation in the trial, or with my results, they will recommend I visit my general practitioner.

I am a New Zealand citizen or permanent resident. I can confirm that I have never been diagnosed with diabetes, cardiovascular disease, or hypertension. I have never suffered a stroke or a deep vein thrombosis. I can also confirm that I am not currently on any medication that alters my blood pressure or blood lipids or cholesterol.

I understand that I should consult my doctor if I am unsure of any of the information in this consent form.
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. If I do withdrawal, I give consent for all previously collected data to be used in the project and will not be expected to provide any more data. I know that I will be supplied with copies of all data upon my request.

At the end of the trial I agree to return all equipment previous supplied, including furniture and electronic movement monitors.

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 supervisors. I also understand that all the information that I give will be stored securely on a computer at Unitec for a period of 10 years.

I consent to being interviewed 3 times throughout the course of the research project and understand that these interviews will be recorded, analysed, and used in the research document. I understand that I will be supplied with transcriptions by written request. I understand an allow examples of my experience to be written in the research document.

I understand and agree to participate in fortnightly questionnaires.

I will be supplied with a diary in which it is optional for me to record my experience throughout my time using a standing desk.

I understand that my identity will be protected and 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: __________________________

Project Researcher: __________________________ Date: __________________________

UREC REGISTRATION NUMBER: 2013-1029
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Appendix E. Ethics approval

Daniel Archer  
19 Telford Ave  
Mt Eden  
Auckland 1041  

22.5.14  

Dear Daniel,  

Your file number for this application: 2013-1029  
Title: Effect of a standing desk intervention on markers of metabolic syndrome in sedentary office workers.  

Your request for amendments to the above ethics application have been reviewed by the Unitec Research Ethics Committee (UREC) and have been approved for the following period:  

Start date: 5.5.14  
Finish date: 15.8.14  

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.  
3. Organisational consent/s must be cited and approved by your primary reader prior to any organisations or corporations participating in your research. You may only conduct research with organisations for which you have consent.  

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

Yours sincerely,  

Gillian Whaitley  
Deputy Chair, UREC  

cc: Rob Moran  
Cynthia Almeida
Appendix F. Actigraph user guide

Using the Actigraph

The Actigraph is a positional sensor that records whether you are in a seated or standing position.

We ask that you wear this for your waking hours where possible. Doing so will allow us to measure how effective a standing up desk is at increasing your daily activity, both at work and after work.

The Actigraph will hold a charge for at least 25 days before charging is required, although this may change depending on how many hours it is worn. Please see below for an explanation of any lights you may encounter.

To Charge

Simply unscrew the small black cap on the side of the Actigraph using a 10 cent coin. Below this is a small socket that the supplied charger will connect to. While charging the green light will flash. When fully charged it will glow solid green.

Replace the screw cap by gently returning it to the side of the device. It can be a little tricky to get it seating correctly before it will screw in properly. Please don’t force it.

Light indicators

Connected to charger

- 1x Flash: Battery is charging
- Solid light: Battery charge complete
- Solid or flashing: Device faulty. Help needed.

Not connected to charger

- No light: Device is operating normally
- Flashing: Device faulty. Help needed.
- 2x Flash: Battery exhausted, please charge
- 3x Flash: Device faulty. Help needed.

If you need any help then please contact Dan on 021 874 913 or email dan@thestandingstudy.co.nz
Appendix G. Self-care exercises

Staying comfortable
Welcome to your new standing desk. We know the endgame, but getting used to standing up at a desk means getting stronger through your legs and core. Unfortunately there is no way around this settling in period, and it is going to mean some aches and pains while you strengthen your body.

In order to help you get ready, we think that a ‘phase in’ period is a good idea. Below is a rough guideline as to how much you might aim to stand for the first 3 weeks while you adjust.

**Week 1**
- 3 days with a total of 1 hour standing each day
- 2 days with a total of 2 hours standing each day

**Week 2**
- 3 days with a total of 3 hours standing each day
- 2 days with a total of 4 hours standing each day

**Week 3**
- 3 days with a total of 5 hours standing each day
- 2 days with a total of 6 hours standing each day

You may choose to stand for five minutes at a time, moving to bouts of 15 minutes of standing and then 30 minutes of standing as you progress. As you get closer to the fourth week we hope that you feel comfortable enough to stand for a large part of the day with regular and short sitting breaks.

Keeping your feet happy
All that standing is means a lot more loading through your feet and comfortable shoes are essential. The first few days and weeks will make for a few aches and pains in your feet, and some gentle massage will help with this. Rolling a tennis ball under your heel and arches can be very therapeutic; pressure can be applied to particularly sore spots.

Moving your legs
A surprising amount of blood is needed in your legs, and gravity wants to keep it down there. To keep this blood moving it is important that you keep your legs moving. Rhythmic muscle
contractions in the legs move venous (used) blood through a series of valves and back up towards your heart.

You might find that rocking side to side or back and forth slowly through your legs helps you reduce fatigue in your legs, as well as having the added bonus of moving blood back up your legs. Actively contracting your quads and calves by shifting weight back and forth between your feet will also help you to stay comfortable as you get used to standing.

You may find that resting one leg against a small foot stool or similar be helpful in reducing aches and pains, swapping when you feel fatigue setting in. A simple calf stretch can be performed by dropping one heel off the back off a step, you should feel a gentle pull in your calf. Hold this for 30 seconds.

**Protect your lower back**

Your lower back depends on muscle strength and tone to stay strong. Two large muscle groups in particular are your abdominal muscles and your gluteal muscles. When we sit for long periods of time we stop using certain muscles. After a while the body gets so used to not using them that it needs to be retrained.

The gluteals can be strengthened while laying on your stomach. As you contract the strong muscles in your buttck, lift the same leg off the ground and hold for 5 seconds. At the same time keep your stomach tight. The strengthening of both your stomach core and gluteals will both help to keep your lumbar spine strong and worry free. As they get stronger, be more aware of keeping a low contraction in both of these muscle groups while standing.

Lots of sitting can lead to tightness in the front of the hip. These muscles attach directly to your lower spine, so stretching them can be excellent in avoiding or relieving lower back pain. With one knee on the ground place the other foot in front of you. Keeping your core muscles contracted, gently rock forwards towards the grounded foot.

Finally, a good low back stretch can be found by rotating gently throughout the entire spine as if you are trying to look behind you. If you sit on the ground with one leg flat on the ground in front of you it will stretch that hamstring, and if you cross one leg over as shown in the picture it will stretch your gluteal as well. Hold for 30 seconds and swap everything over for the other side.
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