Effects of a sit-stand ergonomic intervention on musculoskeletal discomfort in sedentary office workers: a single case design

Whitney Ferguson

A thesis submitted in partial fulfilment of the requirements for the degree of Master of Osteopathy
Unitec Institute of Technology, 2016
DECLARATION

Name of Candidate: Whitney Ferguson

This thesis entitled *Effects of a sit-stand ergonomic intervention on musculoskeletal discomfort in sedentary office workers: a single case design* is submitted in partial fulfilment of the requirements for the degree of Master of Osteopathy.

Candidate’s Declaration

I confirm that:

- This thesis represents my own work; and
- 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: 2013-1076

Candidate Signature:

Student number: 1326694
Date: 19th August 2016
ABSTRACT

Background: Sit-stand workstations have been identified as a strategy to reduce sedentary behaviours in the workplace and may mitigate musculoskeletal symptoms by allowing positional change between sitting and standing.

Aim: The aim was to investigate the effect of a sit-stand workstation on standing time in the workplace. Changes in standing time were examined to determine the responsiveness of musculoskeletal symptoms to increased standing in sedentary office workers.

Design: Two phase single-case series design

Methods: Participants were measured throughout baseline and intervention phases, with the introduction of standing during the intervention phase. Sitting and standing time was objectively monitored through use of a personal inclinometer, in addition to self-reported measures of musculoskeletal discomfort by location, frequency and severity, matched to participant symptoms.

Results: Six symptomatic participants (male n=3, female n= 3, age range 25 to 38 years) employed full-time in sedentary occupations were recruited. A reduction in sitting time was observed for three participants, ranging from 15 min/day to 78 min/day. Sitting time was almost exclusively replaced with standing. Musculoskeletal symptoms improved in Troublesomeness and frequency of episodes with at least one area of discomfort reverting to no symptoms for each participant during the intervention phase. However, in general, changes to musculoskeletal symptoms did not exceed the smallest worthwhile change.

Conclusion: Changes in objectively measured sitting and standing time were small; therefore, results of reduced discomfort during the intervention phase should be interpreted cautiously. Further research is necessary to examine the potential for reduced sedentary behaviours to influence symptoms of musculoskeletal discomfort in the workplace.

Keywords: sit-stand workstation, sedentary behaviour, workplace intervention, work-related musculoskeletal disorders
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<td>Disabilities of the Arm, Shoulder and Hand Questionnaire</td>
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<td>Metabolic Equivalents</td>
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<tr>
<td>NRS</td>
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Chapter 1
INTRODUCTION

An introduction to the research topic and an overview of the thesis rationale, aim and structure
1.1 Sedentary behaviour and the risk of adverse health outcomes

It is now understood that too much sitting is associated with greater risk of negative health outcomes. There is evidence of independent relationships between prolonged sitting and many unfavourable conditions including obesity (Mummery, Schofield, Steele, Eakin & Brown, 2005), cardiac risk, metabolic risk (Stamatakis, Hamer & Dunstan, 2011), cancer (van Uffelen et al., 2010), musculoskeletal discomfort (Bergqvist et al., 1995), psychological distress (Kilpatrick, Sanderson, Blizzard, Teale & Venn, 2013) and all-cause mortality (Proper, Singh, van Mechelen & Chinapaw, 2011). These adverse health outcomes are independent of physical activity levels; and the risk is similar between inactive individuals and individuals for whom physical activity guidelines are met or exceeded (Healy et al., 2008b). To help mitigate the negative health effects of sitting and sedentary behaviour, government agencies such as the Victorian Health Promotion Association in Australia, National Heart Foundation of Australia and the Ministry of Health in New Zealand are beginning to recommend reducing overall sitting time and breaking up periods of prolonged sitting behaviour (Healy et al., 2008a; Ministry of Health, 2015b; National Heart Foundation of Australia, 2012).

Sedentary activities describe a ‘low-energy’ activity such as sitting or lying down and may be present in the workplace, whilst commuting, or during leisure time (Owen, Healy, Matthews & Dunstan, 2010). Sedentary behaviour is distinct from inactivity or insufficient exercise levels that do not meet physical activity guidelines (Owen, 2012; Sedentary Behaviour Research Network, 2012), and is characterized by any waking activity with energy expenditure of ≤1.5 metabolic equivalents (METS) (Owen et al., 2010). Light intensity activities such as standing or light walking require energy expenditure of up to 2.9 METS, while moderate to vigorous activity such as jogging or running requires expenditure of ≥3 METS (Owen, 2012). In this thesis, the term sedentary behaviour refers to sitting and the terms sitting and sitting time will further be used to describe the time spent involved in sedentary behaviours.

Office environments have become synonymous with prolonged sitting in the workplace, and sitting time has been estimated to equate to ~80% of office work hours (Parry & Straker, 2013). Occupational sitting is only a portion of the day for many working age adults, with much of the remainder also being spent in sedentary behaviours such as television viewing, video games and reading (2 hours, 1-2 hours and 0.5 hours respectively (Statistics New Zealand, 2011)). Fifty percent of New Zealand adults report sitting for 4 or more hours per day (Bauman et al., 2011). However, it is likely sedentary time is underreported, given that
only 3-5% of waking hours are spent engaged in moderate to vigorous activity when objectively measured (Healy et al., 2007).

For many adults, sitting in the workplace is a substantial proportion of total daily sitting, and is a crucial modifiable risk factor for the development of work-related musculoskeletal disorders (WMSDs). WMSDs are a group of musculoskeletal complaints arising through workplace exposures, commonly referred to as discomfort. The term *discomfort* is henceforth used to describe WMSDs of non-specific origin. These gradual process complaints are heavily influenced by ergonomic factors (particularly prolonged static or extreme posture), adverse conditions of the working environment, excessive repetition and inadequate rest and recovery (Armstrong et al., 1993). Prolonged static sitting, such as that seen in an office workplace, has long been associated with the development of musculoskeletal discomfort in the neck, low back and legs (Naqvi, 1994). Together with office workers, other occupations such as taxi, truck and bus drivers are also exposed to prolonged sitting and the associated health risks; however, there is more opportunity to modify sedentary behaviour in an office environment than in vehicle operators and thus office workers are a population of considerable interest.

Numerous psychosocial, physical and environmental factors are involved in the presentation of WMSDs and may effect the transition from initial symptoms into a chronic condition. To date, a single specific factor clearly showing a link to the causation of WMSDs has not been identified, despite the findings of multiple studies where office work has been shown to influence the onset of musculoskeletal symptoms in previously asymptomatic participants (Davis, Kotowski, Sharma, Herrmann & Krishnan, 2009; Husemann, Von Mach, Borsotto, Zepf & Scharnbacher, 2009; Robertson, Ciriello & Garabet, 2013). The multifactorial aetiology of WMSDs and wide variety of conditions encompassed by the definition are likely to cause difficulty isolating the many factors in research settings.

Multiple factors such as poor ergonomics, sustained static loading, and psychological stress are present in the office environment (Zemp, Flisser, Wippert, Taylor & Lorenzetti, 2016) and are thought to influence the development of WMSDs in office workers (Calnan, 2002). Westgaard (2000) suggests that modern work demands have become less physically demanding since the early 1990s, while there has also been an increasing emphasis on time efficiency and productivity. As a result, office workers may be at risk of gradual process, low-amplitude biomechanical stressors rather than sudden, single exposure risks.
Ayanniyi, Ukpai and Adeniyi (2010) estimate the point prevalence of musculoskeletal symptoms of computer users to be as high as 93.2% in the past year, in comparison to only 33.9% for non-computer users. In New Zealand, the Accident Compensation Corporation (ACC) provides personal injury cover for residents and visitors, including cover for work-related gradual process injuries. ACC (personal communication, June 7 2016; Appendix E) reports 5,663 new musculoskeletal work-related gradual process claims were accepted in the 2014/15 financial year, with an associated claim cost of $81 million New Zealand dollars paid during the same financial period. There are also substantial indirect costs such as loss of productivity, earnings and tax revenues (Calnan, 2002), which may far exceed the direct costs of WMSD treatment (Lundkvist, Kastang & Kobelt, 2008). Moreover, despite the already high cost associated with accepted claims, 36% of ACC musculoskeletal work-related gradual process claims are declined (ACC, personal communication, June 7 2016; Appendix E) and there are also many workers experiencing WMSDs who do not seek treatment (Bevan, Gunning & Thomas, 2012). Therefore it is likely that the prevalence of WMSDs may be wider than reported.

Sitting is a modifiable risk factor for the development of WMSDs, indicating that office workers may be more susceptible to WMSDs due to the sedentary exposure of prolonged and uninterrupted sitting associated with office based occupations (Parry & Straker, 2013). Through the avoidance of prolonged sedentary time and static postures (Pynt, Higgs & Mackey, 2001), adjustment in posture, breaks from sitting time, and moving from sitting to standing throughout the workday have been the mainstay strategies for alleviating and preventing WMSD symptoms.

To date, there have been multiple intervention studies designed to investigate the reduction of occupational sitting through use of sit-stand workstations (Alkhajah et al., 2012; Healy et al., 2013; Neuhaus, Healy, Dunstan, Owen & Eakin, 2014; Pronk, Katz, Lowry, Rodmyre Payfer, 2012). A sit-stand workstation is a single surface workstation that may be adjusted for use in a sitting or standing position. There are various other terms used to describe a workstation of this nature, such as a sit-stand desk, height-adjustable workstation or simply ‘standing desk’. For this thesis, the term sit-stand workstation will be used hereafter. Research involving sit-stand workstations in office environments has successfully shown a reduction in office sitting time ranging from 66 minutes (Pronk et al., 2012) to 143 minutes per day (Alkhajah et al., 2013). More importantly, workplace sitting time was displaced by standing in all of the studies, a change that has a dual benefit of decreasing overall sitting time and improving metabolic and overall health through increased levels of moderate activity associated with standing.
As evidence continues to emerge regarding the negative impact of sedentary behaviour on WMSDs and other health outcomes, it is becoming increasingly important to investigate options to reduce the exposure to prolonged sitting. Occupational sitting forms a large portion of daily sedentariness, and as a modifiable factor sitting is a logical target for intervention. Sit-stand workstations have been previously investigated in multiple studies; however, to date the focus has been on the reduction of sitting time and increase in physical activity in the workplace. To date, only a limited number of studies address the potential influence of sit-stand workstations on the presentation of WMSDs in sedentary workers. Therefore, it is necessary to further investigate possible interventions aimed at improving worker health and sitting-related discomfort through the reduction of sitting time in the workplace.

1.2 Rationale for study design

Although there is much evidence regarding the negative health outcomes associated with prolonged sitting, the existing literature regarding the role of sit-stand interventions and their affect on WMSDs is limited quantity and widely heterogeneous. The majority of studies use musculoskeletal discomfort as a secondary measure and no studies intentionally recruit symptomatic participants. Ultimately, randomized controlled trials are required to investigate causal links between occupational sit-stand workstations and changes in the presentation of WMSDs. However, given the low number of randomized controlled trials in the existing literature it is first necessary to establish preliminary evidence and research expertise in this area, such as suitability of outcome measures and responsiveness of the participant to the intervention in an established workplace environment. This may be established with lower participant numbers using case studies or time-series designs. Given the prevalence of WMSDs in the workplace and the negative health outcomes associated with prolonged sitting, it is necessary to further investigate the use of sit-stand workstations as interventions for reduction in WMSD symptoms.

1.3 Aim of this thesis

The study reported in this thesis is a longitudinal investigation using a prospective single-case design with the aim of identifying relationships between the use of sit-stand workstations and the presentation of WMSDs in symptomatic sedentary office workers.
1.4 Structure of this thesis

The thesis is structured in seven chapters. Chapter 1 is an overview of sedentary behaviour and the resultant effects on musculoskeletal and overall health. Chapter 2 provides a more in-depth summary of background information in the fields of sedentary behaviour and WMSDs. Chapter 3 is a critical review of the literature examining the levels of evidence established for causal relationships between sit-stand workstations and musculoskeletal discomfort. Chapter 4 outlines the method choice. Chapter 5 describes the methods of the main study, including study design, outcome measures, data collection and analysis. Chapter 6 reports the individual results of each participant. Chapter 7 encompasses the examination, discussion and conclusion of the study results, inclusive of limitations and recommendations for future research.
Chapter 2
AN OVERVIEW OF THE LITERATURE

A synopsis of background information on work-related musculoskeletal disorders and the relationships between sedentary behaviour, the workplace and musculoskeletal health
2.1 Work-Related Musculoskeletal Disorders

2.1.1 Defining work-related musculoskeletal disorders

Work-related musculoskeletal disorders (WMSDs) are injuries to muscles, tendons, circulation, joints, bursae and nerves that occur over time due to repeated occupational trauma. These may be a result of frequent or repetitive activities, excessive muscle stretching or poor posture (Canadian Centre for Occupational Health and Safety, 2005) associated with occupational task requirements or workstation usage. WMSDs may be episodic and non-specific in origin; manifesting in a variety of ways but universally distinguished by periods of intense discomfort impacting the ability of the worker to perform in the workplace (Punnet & Wegman, 2004).

2.1.2 Aetiology of work-related musculoskeletal disorders

It is generally accepted that WMSDs arise due to biomechanical factors such as sustained or constrained postures, repetitive movements or force. All of these factors cause or significantly contribute to the WSMD condition, particularly when of sufficient duration or intensity to overcome the ability of the natural ability of the body to recover. Occupational factors such as excessive workload, psychosocial factors and certain individual characteristics are thought to increase the risk of WMSD symptoms (Spurgeon, Gompertz & Harrington, 1997).

A major review by the National Institute of Occupational Safety and Health (1997) investigating the physical causes of WMSDs reviewed multiple factors potentially causative to WMSD development in the neck, shoulder, elbow, hand/wrist and lower back. The factors included were repetition, which creates cumulative loading; force, which causes excessive mechanical stress; vibration, which causes local neurological and vascular injury; awkward postures, which increase biomechanical loading and a combination of repetition, force and posture. Lifting, heavy physical work and static work posture were also considered as factors for low back pain. The review found that there was ‘strong evidence’ for increased risk of WMSDs when associated with physical workplace factors of posture with neck pain, lifting with low back pain and a combination of repetition, force and posture for elbow pain, carpal tunnel syndrome and hand/wrist tendonitis. Some epidemiological evidence was found of a causal relationship for low back pain with awkward posture and heavy physical work.
WMSDs are uniquely multifactorial, unlike many occupational diseases that arise from specific hazardous agents. There is much controversy regarding pathophysiological mechanisms for the development of WMSDs, largely because of the wide variety of contributing factors and diversity of clinical presentation, in addition to the high potential for the various factors to interact.

2.1.3 Biopsychosocial theories for the development and chronicity of work-related musculoskeletal disorders

The biopsychosocial model is an integrated approach to the various determinants impacting health. In the instance of WMSDs, the pain experience is strongly mediated by psychological and social factors. Clinical or even-subclinical outcomes that occur when an individual experiences musculoskeletal pain are difficult to predict, yet determine the impact on work performance, coping and pain behaviours. The psychosocial concept is based on the effect of both the social aspects in the work environment and the psychological demand of the job role on WMSDs. Stress responses can be triggered by work and present as both systemic and localised changes, repeated exposure to which can contribute to the development or chronicity of WMSDs (Calnan, 2002).

Psychosocial stressors are causal agents that are likely to be identified as noxious or threatening, dependant on the coping process of the individual and their ability to deal with stressful demands (Lazarus, 1993). Stress is a nonspecific response to a physical or psychosocial stressor; both stress and stressors are considered risk factors for the development of muscle pain symptoms (Westgaard, 1999). The National Institute of Occupational Safety and Health (1997) identified three subgroups of psychosocial factors which are considered in relation to WMSDs: 1) factors associated with the job role and working environment, 2) factors relating to the external work environment; and 3) individual characteristics. These are briefly outlined below.

2.1.3.1 Job role and working environment

Job role factors including job satisfaction, monotonous tasks, work relations, demands, stress, and perceived ability to work have been found to have strong evidence in favour of future back pain (Linton, 2001). Poor physical work environment, such as undesirable lighting and temperature of the workspace and high mental stress have also been identified as high predictors of neck pain (Korhonen et al., 2003).
2.1.3.2 External work environment

Factors outside of the work environment include additional responsibilities for care of a parent, spouse or child. A systematic review by Ramond et al. (2011) found no link between social support and outcomes for low back pain. However, the main outcomes measured for this factor were not related to social responsibilities, but rather work status, education level and socio-economic classification. Calnan (2002) describes the complex interaction between biobehavioural processes is directly affected by an individual’s processing of external stressors at home and in the workplace. Therefore, is it likely for level of stress to be variable between individuals and may not necessarily be captured by explanatory randomised controlled trial (RCT) research designs that require homogeneity across participants.

2.1.3.3 Individual characteristics

Lazarus (1993) describes coping as the individual ability to manage demands that are appraised as overwhelming or challenging and is contextually dependant on the stressful condition. The environment is constantly evaluated and these demands are appraised to determine the significance and potential for harm. Appraisal and coping processes therefore modulate the stress reaction and are derived from individual and environmental variables (Lazarus, 1993). This concept is based on the notion that the stress response is dependent on the expectancies in place regarding the personal significance and outcome when encountering a psychological stressor (Krohne, 2001). These theories may explain the relationship between pain behaviours and the development and chronicity of WMSDs and pain experiences in general.

A systematic review by Chou and Shekelle (2010) found individual psychological components such as fear avoidance and higher somatisation scores at the onset of pain to be predictors of disabling low back pain. Similarly, pain-related fear (Swinkels-Meewisse et al., 2006), passive coping (Jones et al., 2006) and self-evaluated risk of persistent low back pain (Henschke et al., 2008) have been associated with increased musculoskeletal recovery time.

Catastrophising and depression have been found to be significant predictors of pain-related disability, independent of a workplace environment (Arnow et al., 2011) and depression is also predictive of prolonged recovery time in low back pain (Henschke et al., 2008). The behavioural responses to pain may be learned (Tyrer, 1986), and elements such as age and previous symptoms are also risk factors for the development of WMSDs (Bongers, de Winter, Kompier & Hildebrandt, 1993).
These psychological and experiential components, when present in individuals also exposed to psychological and biomechanical stressors in the work environment will determine the outcome and persistence of WMSD disability.

2.1.3.4 Physiological responses to stress

The mechanisms by which psychological stressors might contribute to WMSD development are not clearly understood. Davis and Heaney (2000) describe potential causal mechanisms to be biomechanical load on the spine, chemical reactions occurring during stress response and altered pain tolerance.

Spinal loading refers trunk postural and kinematic changes and muscle activity during the stress response. Sjøgaard, Lundberg and Kadefors (2000) hypothesise that mental stressors elicit muscle activity that is both non-postural and involuntary. Certainly, higher levels of muscle tension are associated with rob roles that are more demanding, where employees experience a higher level of mental stress (Bansevicius, Westgaard & Jensen, 1997) and lower job satisfaction (Linton, 2001). Similarly, symptomatic low back pain may be more likely to occur in individuals with higher job stress (Bergenudd & Johnell, 1991). A New Zealand study by Nair, Sagar, Sollers, Consedine & Broadbent (2015) found that self-reported levels of high self-esteem, arousal, positive mood and lower fear were present in participants with upright posture compared to increased stress reactions in slumped participants. A markedly flexed posture has been associated with seated work, independent of the presence of discomfort (Mork & Westgaard, 2009); therefore seated workers may be exposed to the risk of negative stress reactions due to a tendency towards slumping whilst performing office work. Mental stress in computer users has also been shown to increase electrical activity in the trapezius bilaterally (Thorn et al., 2007), suggesting an association between work-related stressors and shoulder or neck WMSDs. The increase in muscle tension in response to stress is dose-dependent, with higher trapezius electromyography derived activity associated with those reporting greater levels of pain or exposed to a larger degree of stress (Westgaard, 1999). Mental stressors modulating muscle electrical activity may increase spinal loading or influence the slumping posture that is correlated with workplace sitting, contributing to the physiological development of WMSDs.

Increased muscle tension is associated with muscle pain (Simons & Mense, 1998) and is also hypothesised to decrease blood flow to muscles due to vasoconstriction (Maeda, 1977) causing accumulation of metabolites (Davis & Heaney, 2000) further contributing to the generation of muscle nociception. Järvholm, Styf, Suurkula & Herberts (1988) showed that
muscle contraction at 10-20% of maximal effort was sufficient to cause partial or total blood flow obstruction, resulting in both muscle fatigue and pain due to ischemia (Sjøgaard, Lundberg & Kadedors, 2000). Long term, repeated exposure such as that which occurs in the workplace increases the risk of damage to poorly vascularised tissue and greater potential for WMSD development. Brantley, Dietz, McKnight, Jones & Tulley (1988) found higher levels of urinary cortisol were present during self-reported high stress periods. Melzack (2001) proposed that sustained cortisol release could produce myopathy, weakness and fatigue of muscle and decalcification of bone due to the mediation of protein breakdown in muscle and inhibition of calcium reuptake in bone. Therefore, some of the deconditioning associated with chronic pain may occur as the result of the cumulative effect of cortisol destruction over time on muscle and bone.

2.1.3.5 Altered response to pain

The presence of psychosocial factors may reduce the pain threshold of an individual, increasing the potential likelihood of reporting a WMSD (Davis & Heaney, 2000). In a workplace, this may be demonstrated by employees in a stressful role or environment reporting more injuries or taking a higher proportion of discomfort-related sick leave than an employee without stress. Theorell, Nordemar, Michelson & Group (1993) found that reduced pain threshold was associated with employees having low decision latitude. Genetic and environmental factors heavily influence interacting variables such as coping mechanisms, which will mediate the response to stressors (Calnan, 2002). This may also explain why individuals respond to the same stressors differently.

Frank, Pulcins, Kerr, Shannon & Stansfield (1995) propose a theory that occupational back pain is a modern issue that has arisen from a combination of low job satisfaction and readily available compensation for illness and injury in the workplace. Correspondingly, the prevalence of chronic low back pain in North Carolina rose from 3.9% in 1995 to 10.2% in 2006 (Freburger, 2009) and in New Zealand both stress levels in the workplace and absenteeism have increased between 2012 and 2014 (BusinessNZ, 2015).

2.1.4 Physiological theories for the development and chronicity of work-related musculoskeletal disorders

There are a number of physiological mechanisms that are thought to be involved in the presentation of WMSDs. Although the mechanisms themselves are widely accepted, the extent to which each interacts or influences the development and chronicity of WMSDs is
debated. The theoretical debate with respect to the relationship between musculoskeletal pain and the many contributing factors is complex and no attempt will be made to summarise it here. A brief overview of the various mechanisms is outlined in the following section to provide an indication of the theories involved in the pathophysiology of WMSDs.

2.1.4.1 Static posture

Zemp et al. (2016) used a pressure mat on the seat of office workers and identified that participants reporting back pain had a clear trend towards static sitting behaviour. Sustained static or constrained postures can contribute to the development of pain when of sufficient duration or intensity to overcome the ability of the natural ability of the body to recover. Abnormal static posture may result in muscle imbalance (Mackinnon & Novak, 1994) or manifest as forward head posture (Weon et al., 2010), compressive neuropathies, or neural tension symptoms of paraesthesia, anaesthesia, burning or shooting pain (Higgs & Mackinnon, 1995). Researchers cannot yet reach a consensus as to whether static posture is causative or resultant from musculoskeletal pain and more research is required to investigate the exposure-response relationship (Zemp et al., 2016).

2.1.4.2 Vascular compression

Compression of capillaries is produced by prolonged muscle tension or repetitive movements, resulting in reduced transmural pressure, narrowing of the lumen and increased resistance to blood flow (Fung, 2013). The clinical outcome of this process is localized ischemia and limited ability of the vascular system to sufficiently perfuse tissue and remove metabolites. Nerve endings may become irritated or similarly compressed by chronic muscle tension, a primary source of peripheral neuropathy symptoms and muscular fatigue. Hagberg (1981) used electromyography to locate evidence of fatigue in muscle fibres that later became injured. Therefore muscular fatigue may be considered a precursor to muscular injury. The ischaemic process involved in vascular compression is also reversible where there is a sufficient recovery period and does not necessarily result in permanent muscular damage, which may explain mild or subclinical symptoms of WMSDs that are solely related to the work cycle.

2.1.4.3 Muscular fatigue or injury

Buckle and Devereux (2002) describe the development of WMSDs as a response to prolonged posture, where the dose response is increased circulation and local muscle fatigue.
Visser and van Dieën (2006) has suggested that there is consistent low-level muscle activation during prolonged static positions, such as those adopted during sustained periods of sedentary behaviour.

Muscles continually exert force during prolonged static contraction but it is rare for all of the motor units innervating a muscle to be activated simultaneously (Tamaki et al., 1998). Edwards and Lippold (1956) found that motor units were recruited at in increasing rate or activated at a higher frequency to maintain a sustained contraction force as the muscle fibres fatigue over time. This is supported by Henneman’s size principle, which involves a fixed order of motor unit recruitment, where small motor units are recruited prior to larger motor units (Henneman et al., 1965). The Cinderella Theory (Hagg, 1991) also states that smaller motor units are recruited constantly during very low levels of muscle tension, and remain active until the entire muscle is relaxed. Thorn et al. (2007) found continued activation of single motor units within the trapezius muscle over long periods of static contraction in a symptomatic computer user population. Forsman, Kadefors, Zhang, Birch & Palmerud (1999) also suggest these low threshold motor units within the trapezius to be active in multiple arm positions. The findings are suggestive of prolonged contraction as a source of nociception in fatigued muscle.

Motor unit recruitment is suggested to rotate during prolonged contraction, as reported by Fallentin, Jørgensen and Simonsen (1993), where motor unit activity disappeared then reappeared minutes later when monitored by electromyography during constant contraction. Alternating recruitment may afford a functional advantage in maintaining contractile force and a greater inherent capacity for motor unit rotation may improve muscular endurance in the individual.

In some cases of low-level constant motor unit recruitment, the opportunity to relax intermittently is reduced (Schleifer et al., 2008). Small motor units are recruited first during muscle contraction. These are low-threshold and comprised of type-1 muscle fibres, which are selectively injured first during prolonged activation of muscle (Larsson, Bengtsson, Bodegard, Hendrilsson & Larsson, 1988). This can result in metabolic overload, leading to pain and strain when such activation occurs for a significant time period or is repeated daily over months or years (Zennaro, Läubli, Krebs, Klipstein & Krueger, 2003).

Muscle pain arises from the activation of nociceptors, high threshold sensory free nerve endings that detect stimuli with the potential to damage the tissue (Woolf, 2011). Nociceptors can become activated by strong mechanical stimuli such as mechanical overloading, in
addition to inflammatory mediators (Mense, 2008). Two main activators of nociceptors are adenosine triphosphate (ATP), which is located in every body cell and released when the tissue is injured and hydrogen ions (H+), which are present in the form of organic acids.

Injured tissue (resulting in the release of ATP) and acidic tissue pH are the main activating factors leading to muscle pain. Mense (2008) states that most pathophysiological changes in muscle tissue are associated with a drop in pH level, such as chronic ischaemia, tonic contraction (muscle spasm), myofascial trigger points, myositis and occupationally induced postural abnormalities. Treaster, Marras, Burr, Sheedy & Hart. (2006) postulate that myofascial trigger points develop as a result of postural stressors specifically during seated computer work.

Nociceptors may be activated both locally and when spinal nerves are compressed. Neuropathic pain generated at the site of spinal nerve compression can spread centrally and towards the nociceptive nerve endings. When activated, muscle nociceptors release neuropeptides including substance P and calcitonin-gene-related peptide (CGRP), resulting in the dilation and increased permeability of local blood vessels. Bradykinin and prostaglandin E2 are endogenous substances that are released by muscle injury and act to increase the sensitivity of nociceptors to external stimuli.

Nociceptor peripheral terminals may become sensitised after injury, reducing the threshold for stimulation (Woolf, 2011). Sensitisation can occur due to peripheral and central stimulation of nociceptors inducing the release of neuropeptides. Symptoms of the resulting inflammation include cell migration, oedema, erythema, hyperalgesia and allodynia (Marchand, Perretti & McMahon, 2005). It is therefore possible for pain to persist in the absence of noxious stimuli, as the central amplification enhances the pain response so that previously innocuous inputs may activate the pain pathway (Woolf, 2011). It is plausible that central sensitisation contributes to clinical hypersensitivity to pain and the spread of pain sensitivity to uninjured tissue.

2.1.4.4 Nerve injury / vibration

Long term occupational exposure to vibration, such as that experienced by workers operating handheld power tools, is known to cause neurovascular disease. Hand-arm vibration syndrome is a WMSD resulting from chronic vibration to the extremity (Davis et al., 2014). Much of the experimental research has been performed on rats. Lundborg, Dahlin, Hansson, Knaje & Necking (1990) showed that vibration exposure in rats resulted in peripheral nerve
fibre damage, particularly to non-mylelinated fibers close to the vibration source. Vibration exposure has been found to induce demyelination of nerve fibres, the resulting reduction in the density of myelinated nerve fibres is thought to account for the nerve compression symptoms such as paraesthesia and reduced touch and temperature sensation (Dahlin et al., 2014). Vibration can also produce symptoms of Raynaud’s phenomenon, such as “white finger” and cold sensitivity (Davis et al., 2014). The symptomatic changes of hand-arm vibration syndrome are reversible if the exposure to vibration is minimal albeit expected recovery time is greater than the length of exposure (Lundborg et al., 1990) but changes may become permanent where exposure is prolonged. Pathological changes have been found in patients with hand-arm vibration syndrome symptoms, such as increased fibroblasts and fibrosis of the perineurium (Dahlin et al., 2014) and hypertrophy of the arterial muscle cells with occasional arteriosclerosis has also been observed (Takeuchi, Fatatsuka, Imanishi & Yamada, 1986).

2.1.4.5 Ligamentous creep

Soft tissues exposed to loading such as that which occurs during sustained spinal flexion, undergo progressive deformation or ‘creep’ characterised by the expulsion of water from spinal tissue over time. Creep results in loss of intervertebral disc height and laxity in the posterior spinal ligaments leading to a reduced resistance to flexion (Adams & Dolan, 1996). The visoelastic recovery time of the creep deformed passive tissue is longer than the time required to produce the deformation (McGill & Brown, 1992). Research by Sánchez-Zuriaga, Adams and Dolan (2010) indicates that prolonged spinal creep can impair the sensorimotor control mechanisms that act alongside the muscle spindle and Golgi tendon organ reflexes to co-ordinate trunk muscle activation in response to excessive loading. A mechanism of injury may therefore be failure of these reflexes to protect the muscle fibres either during prolonged sitting where excessive loading may take place, or after this period when the individual returns to performance of regular activities.

2.1.4.6 Flexion relaxation phenomenon

The flexion relaxation phenomenon is described as a mechanism that allows the passive spinal structures (such as ligaments, tendons and intervertebral discs) to bear the load usually borne by the erector spinae muscles when the spine is in flexion while standing. This is observed as a period of myoelectric silence as the spine forward bends from standing to full trunk flexion. Holleran, Pope, Haugh & Absher (1995) found that while standing, erector spinae muscles were inactive in full flexion or even at 90° of flexion in some participants.
The flexion relaxation phenomenon is also thought to apply to sitting postures. Mörl and Bradl (2013) observed very low lumbar muscle activation (below the minimum resolution limit of the measurement device) when the lumbar spine curvature was in marked kyphosis. There is also muscle contraction delay after prolonged stretch of the dorsal ligaments and muscle fatigue (Snijders, Hermans, Niesing, Kleinresink & Pool-Goudzwaard, 2008), both of which occur during long periods of sitting. This may increase the predisposition for seated workers to develop discogenic injury, due to the increase intradiscal pressure in the seated position and lack of muscular support for the non-contractile elements of the spine.

The pathophysiological theories regarding the aetiology of WMDs share a common theme of stasis and overuse, with a dose-response relationship between fewer rest periods and a greater degree of discomfort. Insufficient time for tissue regeneration and recovery reduces the ability of the tissue to compensate for further changes, thus purporting the cycle of static posture and overuse causing tissue fatigue and eventual damage.

2.1.5 Prevalence of work-related musculoskeletal disorders

The variety of WMSD symptoms and clinical presentations poses difficulties when evaluating the prevalence and financial burden of WMSDs may be significantly underestimated.

In New Zealand, ACC claim statistics provide comprehensive information on the frequency and type of workplace discomfort, pain and injury claims as well as the resulting medical and wage costs. Approximately 6,300 new work-related ACC claims were made in the 2008/09 period for back injuries alone (Bevan, Gunning & Thomas, 2012). However, ACC coverage does not often extend to chronic, gradual process or overuse injuries, except where the cause is directly attributable to the work environment. It is therefore probable that the ACC data is underreporting the prevalence of some WMSDs given the insidious and multifactorial nature of many WMSD conditions.

An epidemiological study in New Zealand (Harcombe & McBride, 2009) found the point prevalence of upper extremity disorders alone to be 48% in office workers. Of the entire study, 88% of participants reported WMSDs in the previous year, 15% of whom had up to 5 days sick leave as a result of this WMSD. The European Commission (2010) estimates that 60% of all work absences lasting three or more days may be attributable to all-cause MSDs.

Patel et al. (2012) found substantial negative impact on work-related outcomes as a result of chronic pain in the European workplace, such as employment loss, early retirement, sickness
absence and loss of productivity due to ‘presenteeism’. In New Zealand, despite a trend toward decreasing levels of presenteeism, 35% of the workforce continues to come to work despite illness that should have kept them at home (BusinessNZ, 2015).

The subsequent pain and disability arising from WMSDs negatively affects the quality of working life of employees. Such disorders can result in high amounts of sick leave (Westgaard & Winkel, 2011) and significant burden to their family, employer and organization (Öztuğ & Cowie, 2011).

2.1.6 Financial burden of work-related musculoskeletal disorders

The direct costs of WMSDs in New Zealand, such as medical expenses, manual therapy and rehabilitation, were estimated to be between 4-8% of GDP for the year of 2002 (Bevan, Gunning & Thomas, 2012). More recently, ACC injury statistics estimate annual WMSD related claim expenditure in New Zealand in the 2014-2015 period to be ~$71 million excluding GST (ACC, personal communication, June 7 2016; Appendix E). However, a significant portion (≤ 1/3) of ACC claims are declined (ACC, personal communication, June 7 2016; Appendix E) suggesting that the prevalence of injuries and the subsequent treatment cost is higher than the data captured by ACC. Moreover, WMSDs are an injury subgroup that is more likely to result in a declined ACC claim, given that a specific causative factor must be identified in order for the claim to be accepted.

Indirect costs including productivity loss and lost earnings and intangible costs including stress and reduced quality of life may equate to a financial burden greater than that of the direct costs of treatment (Lundkvist, Kastang & Kobelt, 2008). A 2001 report by the National Research Council (US) and Institute of Medicine (US) Panel on Musculoskeletal Disorders and the Workplace estimated the total annual economic burden of WMSDs to be as high as $54 billion in the United States. The financial cost of WMSDs is borne not only by employers and the individual, but also by the community in the form of social welfare, medical costs and lost tax revenues (Industry Commission, 1995). Furthermore, Bevan, Gunning and Thomas (2012) suggest that many workers experiencing WMSDs do not seek treatment, giving rise to the potential for substantially greater costs associated with unquantified WMSD experiences.
2.2 Sedentary Behaviour and Health Outcomes

2.2.1 Sedentary behaviour

The term ‘sedentary behaviour’ was previously defined as a lack of physical activity, or failure to meet physical activity guidelines (Sedentary Behaviour Research Network, 2012), but the term has more recently been used to describe prolonged sitting. Sedentary behaviour is distinct from other forms of other physical activity, including light to moderate activity and is characterized by any waking activity with energy expenditure of \( \leq 1.5 \) METs (Owen et al., 2010). It includes activities such as watching television (Schofield, Kilding, Freese, Alison & White, 2009; Shields & Tremblay, 2008), and office work (Parry & Straker, 2013; Stamatakis et al., 2011). In contrast, light intensity activity such as standing and walking requires expenditure of \( \leq 2.9 \) METS and moderate to vigorous activity has an energy expenditure of \( \geq 3 \) METs. The New Zealand Ministry of Health recommends regular exercise at a moderate to vigorous level for 2 ½ hours spread throughout the week (Ministry of Health, 2015a), however, the New Zealand Health Survey (Ministry of Health, 2014) found that only half of the adults surveyed (51%) met these criteria. Even for those individuals who are regularly physically active, there is also potential to have a high level of sedentary behaviour (Owen et al. 2010); for example, the office worker that goes to the gym or plays a sport outside of their working hours, but spends the majority of their weekdays sitting in the workplace or during the commute between work and home.

Sitting time is considered a proxy measure for evaluating sedentary behaviour. In some instances, screen time has also been used as a marker of sitting time in order to represent sedentary behaviour (Stamatakis et al., 2011; van Uffelen et al, 2010; Williams, Raynor & Ciccolo, 2008). Western societies have begun to spend increased amounts of time sitting, leading to identification of three main categories of sitting: occupational, transport and leisure (Katzmarzyk, 2010).

2.2.2 Sedentary behaviour in the workplace

An epidemiological study in 20 countries (Bauman, 2011) found that half of the New Zealand respondents self-reported sitting for 4 or more hours per day with 13.6% sitting more than 9 hours per day. A 2015 report indicates that 92% of New Zealanders watch an average of 20.5 hours of television per week (The Nielsen Company, 2015), and is the largest contributor to leisure-time sitting. However, the majority of sedentary time is likely to be spent in the workplace, with 79% of men and 46% of women in New Zealand working for 40 hours or
more per week, the standard working hours for most OECD countries (OECD, 2011). Of New Zealand employees, 38% of men and 14% of women work more than 45 hours per week (OECD, 2006).

The rise in computer use and desk based office tasks has made sitting ubiquitous in office workplaces. Office work is a low activity occupation and is considered to be a sedentary behaviour (Parry & Straker, 2013). Sitting in the workplace contributes to over half of total weekday sitting time (Miller & Brown, 2004) and twice the time spent in sedentary leisure activity such as television watching and computer use at home. Sitting time is estimated to account for 81.8% of working hours (Parry & Straker, 2013) and 70% of the entire work day (Thorp et al., 2009) for office workers, compared to 62% of time spent in sedentary behaviours on non-work days (Thorp et al., 2009).

Healy et al. (2012) suggest that whilst there is a lack of empirical data, sedentary behaviour in the workplace is considered to have increased with the growth of the digital age. This is largely a result of computer use becoming increasingly common in workplaces due to the rise of Information and Communication Technology in the last 50 years (Statistics New Zealand, 2009). Computers are now employed in almost every occupational field and are largely used in a seated position or using a seated workstation. This incorporation has caused changes to both work organization and physical demand on workers (Ortiz-Hernández et al., 2003).

2.2.3 The negative impact of prolonged sitting

The ergonomic literature has strongly supported the concept of ‘dynamic sitting’ in the workplace, as there is not thought to be a singular ideal sitting posture (Pynt, Higgs & Mackey, 2001; Zemp et al., 2016). Dynamic sitting is achieved by altering the sitting position as often as possible whilst maintaining the lumbar lordosis. Static sitting position has an influence on intervertebral disc pressure, muscle activation and loading of the spine, therefore it is reasonable to conclude that office workers should utilise dynamic sitting in the workplace. The health risks associated with sedentary behaviour are also influenced by the manner in which the sedentary time is accumulated, with longer bouts of sitting associated with biological markers of metabolic risk such as larger waist circumference and fasting plasma glucose (Healy, Matthews, Dunstan, Winkler & Owen, 2011). To this end, interruption of sitting time has become a focus in metabolic health research.
Breaking up prolonged sitting has been shown to lower resting blood pressure (Larsen et al., 2014), reduce postprandial glucose (Dunstan et al., 2012b) and improve the cardiometabolic profile of at risk children with a history of familial obesity (Saunders et al., 2013).

Womersley and May (2006) found that participants reporting postural backache had longer periods of uninterrupted sitting time than asymptomatic participants. This may be due to the inherent nature of sitting in fixed positions, as supported by Roelofs and Straker (2002) who investigated bank tellers that only sit, only stand, or sit and stand, at work. The authors identified the range of movement present during static sitting to be 50 seconds to 52 minutes compared to the range of static standing at 10 seconds to 13 minutes. Postural awareness can be difficult whilst sitting during the performance of work tasks and can be inaccurate in terms of both body position (Phillips, 1999) and self-reported time spent in static sitting (Daian, van Ruiten, Visser & Zubic, 2007).

Due to the widespread use of computers and office-based occupations, relatively small risks associated with the sedentary nature of these conditions can have a cumulative impact on worker health. Furthermore, sedentary behaviours appear to displace time involved in light intensity activities such as standing and walking (Dunstan, Howard, Healy & Owen, 2012a). There is emerging concern regarding the risk of occupational sedentary behaviour on sedentary exposure and general health outcomes (Straker & Mathiassen, 2009).

2.2.4 Sedentary behaviour, cardiometabolic risk and morbidity

There is growing evidence that increased sitting time is linked to increased risk of diabetes mellitus (van Uffelen et al., 2010), cardiovascular disease (Katzmarzyk, Church, Criag & Bouchard, 2009) and all-cause mortality (Patel et al., 2010) despite concurrent exercise at recommended levels. In fact, women meeting or exceeding recommended exercise levels spend only marginally less time sitting per week than those who exercise at lower intensities or not at all (Craft et al., 2012). As such, they are exposed to the same risk factors for the development of chronic disease that arise from prolonged sitting as those exercising below recommended levels.

Many of the studies linking sedentary behaviours to adverse affects have focused on outcome measures of television watching and screen time behaviour. Recent reviews by Williams, Raynor and Ciccolo (2008) and Thorp, Owen, Neuhaus & Dunstan (2011) indicate a positive correlation between television viewing time and health outcomes such as obesity, hypercholesterolemia, hypertension and type II diabetes. Another longitudinal study
(Stamatakis et al., 2011) indicates a strong relationship between recreational screen-based entertainment and increased cardiovascular risk regardless of the level of participation in physical activity.

Similarly, Patel et al. (2010) indicate a 94% increase in all cause mortality in female and 48% in male participants with low levels of physical activity who sat more than 6 hours daily when compared to participants that sat for less than 3 hours per day.

A recent study (McManus et al., 2015) measured the effect of 3 hours of uninterrupted sitting on vascular function of girls aged between 7 and 10. A 33% reduction in flow-mediated dilation of the femoral artery was reported, however, this outcome was completely eliminated for participants that interrupted each hour of sitting with a modest 10 minutes of physical activity. Similarly, changes in vascular tone and structural remodelling of the arterial wall have also been detected in studies observing inactivity and vasculature (Thijssen, Green & Hopman, 2011). These structural changes pose a mechanistic explanation for the impact of sedentary behaviour on cardiometabolic health as an independent risk factor from physical activity.

2.2.5 Sedentary behaviour and cancer

Sedentary behaviours may increase the risk of certain types of cancer. On comparison of high sedentary behaviour levels to the lowest levels, a statistically significant risk has been identified for colon, endometrial and lung cancer (Schmid & Leitzmann (2014). Another systematic review identified associations between sedentary behaviour and endometrial, ovarian and prostate cancer risk (Lynch, 2010). Schmid and Leitzmann (2014) also identify that the risk increased with each 2-hourly increase in daily sitting time. Most importantly the effect is independent of physical activity, therefore it is possible for high proportions of daily sitting to be equally unfavourable for individuals that are physically active. In contrast to these findings, Proper et al. (2011) found no evidence for a relationship between sedentary behaviour and mortality from cancer, possibly due to the relatively high survival rate of some cancers particularly when detected early (American Cancer Society, 2016).

2.2.6 Sedentary behaviour and mental health

There is a link between sedentary exposure and psychological disorders such as psychological distress (Kilpatrick et al., 2013), depression (Zhai, Zhang & Zhang, 2014) and anxiety (Teychenne, Costigan & Parker, 2015). A 2013 survey of government employees in
Tasmania, Australia (Kilpatrick et al., 2013), investigated the association between sitting and psychological distress. The Kessler Psychological Distress scale was used to measure the degree of psychological distress, a tool that is predictive of clinically diagnosable depression or anxiety related disorder (Slade, Grove & Burgess, 2011). It was found that workers who sat for 6 or more hours per day had increased prevalence of psychological distress in comparison to workers that sat for 3 or less hours per day (relative risk = 1.9 for a moderate increased prevalence for men, 1.25 for a moderate increased prevalence for women and 1.76 for a high increased prevalence in women). Similar results were also reported by Sloan et al. (2013), where a high level of sedentary behaviour was associated with increased odds (OR = 1.29) of psychological distress. The authors also identified an inverse correlation of psychological distress (OR = 0.61) for participants that met the guidelines for recommended levels of physical activity and had fewer than 5 hours per day spent in sedentary behaviours.

Critical reviews have identified relationships between sedentary behaviour and anxiety; and between sedentary behaviour and depression in both adolescents (Biddle & Asare, 2011) and in adults (Teychenne, Ball & Salmon, 2010). However, the reviewers report that results were limited by methodological weaknesses in the studies and only small to moderate effect sizes. A later meta-analysis (Zhai, Zhang & Zhang, 2014) was able to calculate the relative risk of depression versus sedentary behaviour as 1.25 across all of the included studies. In this instance the authors report that the literature included had adjusted for potential confounders and exhibited only a moderate level of heterogeneity that was eliminated (0%) once the leave-one-out sensitivity analysis was completed.

It is not yet possible to confirm causal relationships between sedentary behaviour, and depression, anxiety or psychological distress due to the cross-sectional and longitudinal nature of the research analysed. Most reviews conclude that there is limited existing observational research and that the studies reviewed are both heterogeneous and varied in quality. It is as yet unconfirmed whether sedentary behaviour negatively modulates mental health and the authors universally suggest further clinical trials are required to establish the mechanism of the associations. It is possible that psychological health is the determinant for sedentary behaviour, with altered psychological states predisposing sedentary risk; or that a more complex interrelationship exacerbates both conditions when coexistent.

2.2.7 Sedentary behaviour and musculoskeletal health

A low physical workload is suggested to be present in sedentary computer based tasks and during office work in particular (Straker & Mathiassen, 2009). Office workers have been
shown to perform only half the daily steps of blue collar workers (Schofield, Badlands & Oliver, 2005), and spend as much as 81% of the workday involved in sedentary behaviours (Parry & Straker, 2013). Insufficient physical stress is known to detrimentally affect strength, circulation, muscle mass and bone density in response to deconditioning. Many early studies regarding deconditioning were primarily centred on microgravity environments experienced by astronauts. Prolonged bed rest was predominantly used as a proxy measure of microgravity due to the resulting reduction in functional capacity of multiple body systems.

The musculoskeletal system functions optimally when actively supporting the body in an upright position to counteract the effect of gravity (Stuempfle & Drury, 2007). Musculoskeletal deconditioning may occur in as little as 1-2 days of bed rest (Greenleaf & Kozlowski, 1982) and has also been noted to occur from simply reducing weekly weight-bearing exercise time (Coyle et al., 1984). The resultant skeletal muscle atrophy and demineralisation of long bones (Greenleaf, 1989) is due to decreased muscle contraction and reduced weight bearing causing structural changes in the tissue and deficits in oxygen delivery (Stuempfle & Drury, 2007).

Muscle mass and fibre cross sectional area are reduced, predominantly in fast-twitch muscle fibres (Bloomfield, 1997) and strength has been shown to be reduced by up to 20% in knee extensors after 30 days of bed rest (Dudley, Duvoisin, Convertino & Buchanan, 1989). Widrick et al. (1999) found that after a 17 day spaceflight, the soleus muscle fibres of astronauts exposed to microgravity environments showed an increase in shortening velocity and a reduction in Ca$^{2+}$ sensitivity, therefore impairing the production of muscular force.

The absence of longitudinal compressive loading whilst weight bearing causes calcium resorption, from an imbalance between osteoblastic and osteoclastic activity, with excess serum calcium secreted in urine and faecal matter (Bloomfield, 1997; Stuempfle & Drury, 2007). The negative calcium balance ultimately results in decreased bone mass. Prolonged bed rest in healthy volunteers has shown to reduce bone mineral density in weight bearing bones such as the calcaneus (-10%), tibia (-2%) and lumbar spine (-4%) over 4 months of bed rest; no change was seen in the bone mineral density of the radius (LeBlanc, Schneider, Evans, Engelbretson & Krebs, 1990), further confirming the requirement for compressive loading of the lower extremities and spine to necessitate adequate bone mineral density.

Whilst not directly applicable to sedentary behaviours, comparisons may be recognised between prolonged bed rest and prolonged sedentary exposure, particularly when contemporaneous physical activity is below recommended levels. Parallels may be drawn
between the affect on the cardiometabolic system of both prolonged bed rest and high levels of sedentary exposure, where both circumstances result in altered glucose tolerance, cardiac function and increased body fat (Greenleaf & Kozlowski, 1982; Healy et al., 2008b). Therefore, musculoskeletal health is likely to experience similar deleterious effects in response to sedentary exposure.
2.3. **Sedentary Behaviour and Work Related Musculoskeletal Disorders**

The epidemiology of WMSDs has been researched extensively in various occupational populations and correlates highly with keyboard (Gerr et al., 2004), mouse (Blatter & Bongers, 2002) and computer use (Brandt et al., 2004; Korhan & Mackieh, 2010; Ortiz-Hernández et al., 2003). This may be a result of WMSD association with prolonged static non-neutral sitting posture (Caneiro et al., 2010; Korhan & Mackieh, 2010; Szeto, Straker & O’Sullivan, 2005), due to the relationship of computers with seated workstations.

Posture is a major determinant of passive tissue stress and will define how stress is shared between tissues. The requirement for prolonged sitting in modern occupations can restrict worker postures due to workstation confinement and constraints of tasks and equipment. Office workers often use only a few sitting positions and may be more prone to poor posture, as there is difficulty maintaining an awareness of sitting position during concentrated working (Haller et al., 2011).

The reduction in posture variation results in pain associated with static loading of muscles (Corlett, 2008) and non-contractile elements such as ligaments (Wang, Weiss, Haggerty & Heath, 2014). Sitting is a well-recognized factor for the development of neck (Ariëns et al., 2001), shoulder and upper limb (Korhonen et al., 2003; Ortiz-Hernández et al., 2003) musculoskeletal discomfort in seated computer users. There is evidence that an increased angle of lower cervical flexion may occur in computer users, increasing muscular loading of the neck and shoulders and therefore contributing to WMSD symptoms in the upper body when static and sustained for long periods (Szeto, Straker & Raine, 2002).

A major National Institute of Occupational Safety and Health (1997) review into the physical causes of WMSDs found insufficient evidence to determine a relationship between low back pain and static posture. Earlier studies have found sitting to be a risk factor for the development of low back pain (Andersson, 1981; Frymoyer, 1980; Kelsey, 1975; Kelsey & White, 1980). However, recent systematic reviews (Hartvigsen, Leboeuf-Yde, Lings & Corder, 2000; Kwon, Roffey, Bishop, Dagenais & Wai, 2011; Lis, Black, Korn & Nordin, 2007; Roffey, Wai, Bishop, Kwon & Dagenais, 2010) found that the epidemiological literature included in the studies did not demonstrate an independent causal relationship between sitting and low back pain. It is difficult to draw comparisons in low back pain research, as the individual studies included in the reviews are widely heterogeneous in methods, data collection and reporting and even the definition of low back pain.
WMSDs are multifactorial, which may cause difficulty isolating the various factors in research. Coggon et al. (2013) investigated disabling musculoskeletal pain in working populations across 18 countries and 47 occupational groups. Findings indicate a large international variation in the prevalence of disabling musculoskeletal pain, amongst occupational groups of a similar type (i.e. nurses and office workers), even after other known risk factors were accounted for. Therefore, the findings of the National Institute of Occupational Safety and Health (1997) and Hartvigsen et al. (2000) may potentially be explained by the limited ability of researchers to control for the multifactorial phenomenon of WMSDs, and the insidious nature of low back pain specifically. Kwon et al. (2011) emphasise that this may be due to limited or poor quality scientific literature and difficulty identifying evidence of a causal relationship. Heterogeneity in the methods, data and reporting of the studies included in systematic reviews reduces the ability to compare results and extrapolate conclusions regarding a relationship between sitting and low back pain. Universally, the studies included in the systematic reviews recruit participants with non-specific ‘low back pain’, a term used to describe chronic low back pain where no radiologic abnormality is detected (Dillingham, 1995). Instead, specific low back pain subgroups may be required to identify variances between groups; as other studies have revealed differences in sitting posture and trunk muscle activity in patients with non-specific low back pain only when subclassified (Astfalck et al., 2010; Dankaerts, O’Sullivan, Burnett & Straker, 2006; Sheeran, Sparkes, Caterson, Busse-Morris & van Duersen, 2012).

Sitting is associated with flexion of the lumbar, thoracic and lower cervical spine unless a very upright sitting posture is maintained, in comparison to walking and standing where the lumbar spine is lordotic (McKenzie & May, 2003). Flexion of the knee and hip whilst sitting causes posterior tilt of the pelvis and is associated with significantly decreased lumbar lordosis in multiple sitting positions (Cho et al., 2015).

Sitting for long periods generates a flexed posture (Endo et al., 2012). Wormersley and May (2006) found participants with backache had a greater degree of spinal flexion during relaxed sitting compared to those without backache. Long-term sedentary activity will cause decreased lumbar curvature, elongation of posterior spinal structures (Coury, 1998) and continuous loading on lumbar intervertebral discs that is more than the usual weight of the torso (Corlett, 2008; Coury, 1998). During sitting, there is movement of the centre of gravity anteriorly, secondary to flattening of the lumbar spine and ligamentous creep. Thus, the load on the already flattened paraspinal muscles increases as they are forced to contract to prevent the sitter folding forward (Corlett, 2008). Flexion of the lumbar spine may also increase anterior compression on the intervertebral disc and posterior displacement of the nucleus.
pulposus. An early epidemiological study by Kelsey and Ostfeld (1975) indicated a link between sedentary occupations and acute herniation of lumbar intervertebral discs, which may be a result of increased disc pressure while sitting.

Insufficient time for tissue regeneration and recovery reduces the ability of the tissue to compensate for further changes, thus extending the cycle of static posture causing tissue fatigue and eventual damage. Recovery from such static loading can take up to twelve times as long as the time taken for pain to occur, in contrast to recovery from rapid and dynamic muscle contraction (Milner, Corlett & O’Brien, 1986). This effect is compounded by increased sitting time (Coury, 1998), as there is evidence of a dose-response relationship between posture and musculoskeletal discomfort (Kamwendo et al., 1991). Limited muscle rest is therefore also a risk factor for WMSD development. Given that a standard full time working week is 40 hours and the nature of job roles is predominantly seated, seated workers may perform a similar role in the same posture throughout the course of a working career spanning multiple decades.

Some workers continue to work despite such symptoms, an increasing phenomenon described as sickness ‘presenteeism’ (Coole et al., 2010). A cross-sectional study by Aronsson et al. (2000) of the Swedish workforce found that over half their sample had attended work at least one day in the previous year when, according to self-reported health status, they should have taken sick leave. It was also found that upper back and neck pain was the most common reason for presenteeism. Such behaviour may be detrimental long term for both the individual and for their work performance and company productivity (Coole et al., 2010).

Stress is a common occurrence in the workplace and may become a concern when the causative factors are ongoing and there is no return to ‘normal’ in a reasonable timeframe (Worksafe New Zealand, 2013). An employee focus group study (Gilson, Burton, van Uffelen & Brown, 2011) reported that employees identified prolonged occupational sitting with fatigue, de-motivation and feeling “down” in addition to musculoskeletal issues. Prolonged sitting time increases the prevalence of the presentation of psychological distress (Kilpatrick et al., 2013), anxiety (Teychenne, Costigan & Parker, 2015) and depression (Zhai, Zhang & Zhang, 2014) and likely impacts mental health, particularly workers spending the predominant part of a working day seated.

Extended use of the same seated posture for long periods over months or years can result in distortion as physical compensation patterns develop, hypothesised to result in degenerative, inflammatory and fibrotic changes that cause chronic pain to develop (Langevin & Sherman,
2007). It is also plausible that depression and pain (symptoms that often occur together and are labelled as ‘depression-pain syndrome’) amongst other measures of mental health (Lindsay & Wyckoff, 1981) may be modulated by sitting time. Many factors contribute to WMSD presentation and development in seated workers and there is a high level of interdependency and interaction between the factors. Hypothetically, by controlling sedentary exposure in the workplace many causative factors may be down-regulated or eliminated and the prevalence of WSMDs reduced.
2.4 Workplace Intervention Strategies

2.4.1 Interrupting prolonged sitting

Much of research regarding sitting and WMSDs has been focused on improving worker posture and breaking up periods of uninterrupted sitting. For WMSDs specifically, research has largely surrounded interventions that maintain a seated position but attempt to ameliorate the musculoskeletal impact of prolonged sitting or computer use; such as micro pauses (Mclean, Tingley, Scott & Rickards, 2001), ergonomic education (Mahmud, Kenny, Zein & Hassan 2015) and altering aspects of the workstation including the keyboard, mouse and chair (Paul, Leuder, Selner & Limaye, 1996; Probst et al., 2013). The introduction of micro pauses during sustained muscle activation and preventing WMSD symptoms is thought to allow a ‘washout’ of metabolites and restore homeostasis to the interstitial fluid; thereby reducing fatigue or ischaemic muscle pain (Sjøgaard, Lundborg & Kadefors, 2000).

Postural adjustments, breaks from sitting time and moving from sitting to standing throughout the workday have been proposed as strategies for alleviating discomfort and avoiding prolonged static postures (Pynt, Higgs & Mackey, 2001). The purpose of postural variation is to utilise a variety of muscle groups at alternating periods, to provide a relaxation period for overloaded muscle motor units and viscoelastic recovery time of creep deformed passive tissue. Mathiassen (2006) suggests that variation may be insufficient in itself, the breaks or changes in posture must also differ to an extent where there is also diversity between postures adopted. By introducing as much change as possible biomechanical exposure is reduced, as there is variety in position, movement frequencies and task requirements.

Interestingly, interrupting sustained sitting has also been shown to positively affect cardiometabolic markers (Dunstan et al., 2012b; Saunders et al., 2013) and waist circumference (Healy et al., 2008a). Only 5 minutes of standing each half hour (walking or moderate activity is not necessarily required) is sufficient to improve postprandial glucose metabolism (Henson et al., 2016). This is reflected in the New Zealand Ministry of Health (2015b) guidelines that suggest breaking up sitting time by at least a few minutes of every hour. Ryan et al. (2011) found that randomly selected participants with sedentary occupations did not meet different current recommendations for limiting sitting time. No participants met the recommendation of limiting sitting to 20 or 30 minutes and only 8% met the 55-minute recommended sitting limit. The results are suggestive that awareness of sitting recommendations may be limited or that further action is required to implement workplace interventions and ensure workers reduce sitting time to a recommended level.
A systematic review undertaken by Chau et al. (2010) indicated that most recent workplace interventions have been aimed at increasing physical activity, with a reduction in sitting as a secondary outcome. Moreover, measures of sitting were usually self-reported and therefore prone to bias. Other research involving workplace interventions for sedentary behaviour have been focused on the impact of walking treadmill desks on energy expenditure (Levine & Miller, 2007), task performance (Ohlinger, Horn, Berg & Cox, 2011) and the number of daily steps (Thompson, Foster, Eide & Levine, 2008).

2.4.2 Standing workstations

Standing workstations have been in use as early as the 1700s, where Thomas Jefferson was famed for his tall desk that had an angled surface to accommodate a folio (The Jefferson Foundation, 2003). An 1899 book, School Hygiene (Kotelman, 1899), suggested that too much sitting is “liable to injure the abdominal organs and the circulation” and therefore suggested that standing desks be implemented in classrooms. Modern standing desks are largely similar to early models, with a fixed height surface designed for use in a standing position or with use of a high stool.

As with prolonged sitting, prolonged standing also results in non-desirable physiological responses such as peripheral pooling of blood and in the case of static standing, cessation of venous muscle pump due to lack of contracture in the calf muscle (Recek, 2013) and WMSDs due to fatigue (Waters & Dick, 2015). To reduce the negative effects of standing, the Canadian Centre for Occupational Health & Safety (2014) suggests changing positions frequently and incorporating periods of rest, in addition to workstation adaptation to include cushioned floor mats or foot rests to alleviate pressure on the limbs. The concept that postural variation is key to preventing and ameliorating WMSDs appears to be a key principle of both standing and sitting literature, with prolonged duration and limited degree of movement the greatest risks for WMSDs in both environments.

2.4.3 Sit-stand workstations

Sit-stand workstations are those that may be used in either a sitting or standing position where alternating between sitting and standing surface height is accomplished with use of a crank handle or electric motor. It is also possible to add structures to an existing fixed height seated desk to raise the keyboard, mouse and screen in order to have these components at a height suitable for use whilst standing.
Through operation of a sit-stand workstation the user can alternate between sitting and standing throughout the working day. Incorporation of postural variation has been shown to alleviate musculoskeletal symptoms experienced due to fatigue or limited movement in a single position (Fenety & Walker, 20002); therefore sit-stand workstations offer an opportunity for this process to occur to a greater extent than seated workstation exercises alone.

Thus far, investigation regarding the reduction of sitting largely includes studies that are focused on increasing physical activity, using the workplace as a method of approaching individuals and implementing light activity. Current studies show a high correlation of sit-stand workstations with a decrease in total sitting time of as much as 143 minutes per day (Alkhajah et al., 2012) and interruption of prolonged sitting time in the workplace (Gorman, 2012; Healy et al., 2013; Straker, Abbott, Heiden, Matthiassen & Toomingas, 2013).

Implementation of sit-stand workstations has also been positively utilised to ameliorate the onset of musculoskeletal symptoms in previously asymptomatic participants, in comparison to participants using a standard seated workstation (Davis & Kotowski, 2014; Karakolis, Barrett & Callaghan, 2016). Participants suffering musculoskeletal discomfort compared to those without pain may be more likely to use the standing function of a sit-stand workstation (Wilks, Mortimer & Nylén, 2006).

As yet, an ideal ratio of sitting to standing when using a sit-stand workstation has not been identified (Karakolis & Callaghan, 2014). A reduced incidence of musculoskeletal discomfort has been observed using ratios of 1:1 (Roelofs & Straker, 2002; Thorp, Kingwell, Owen & Dunstan, 2014), 2:1 (Husemann et al., 2009) and 3:1 (Karakolis, Barrett & Callaghan, 2016), with reductions in sitting of as little as 8 minutes per hour having a positive influence on reports of musculoskeletal symptoms (Hedge, 2004). However, more frequent transitions between sitting and standing may have a negative effect on productivity depending on the degree of interruption the transition creates. It has been suggested further research is required to generate guidelines for optimal usage and employee training (Karakolis & Callaghan, 2014).
2.5 Conclusion

Sitting is considered a sedentary behaviour and has been shown to correlate highly with poor metabolic and cardiovascular health outcomes and all-cause mortality (Proper et al., 2011; Stamatakis et al., 2011; van Uffelen et al., 2010). Musculoskeletal discomfort and WMSDs are also associated with prolonged sedentary behaviours (Bergqvist, Wolgast, Nilsson & Vost, 1995).

Office workers are exposed to prolonged and uninterrupted sitting and may be more susceptible to the resultant detrimental effects. Sitting time accounts for over 80% of office hours (Parry & Straker, 2013) and is often accumulated in long bouts with infrequent rest breaks (Ryan, Grant, Dall & Granat, 2011). Furthermore, other workplace factors influence the relationship between sitting time and discomfort, such as psychological distress and work environment, creating a multifactorial symbiotic relationship.

Unsurprisingly, a substantial proportion of sedentary behaviour research has aimed to use the workplace as a venue to modify sitting time and implement strategies for improving health and changing behaviours. Ergonomic changes to the chair, mouse, keyboard or all of the above, in addition to ergonomic education are the current mainstream practice for addressing WMSDs in the workplace. Some studies have focused on alternatives to sedentary activity through use of walking treadmill desks (Levine & Miller, 2007) bicycle desks or elliptical trainer desks (Commissaris et al., 2014), however the financial constraints and limited practicality of these dynamic workstations is a barrier for widespread utilisation in the workplace.

Sit-stand workstations, or variants of a standing capable workstation, offer an easily accessible and affordable option for workplaces to implement changes to sedentary behaviour of workers. The majority of office workplaces have standard seated height workstations, which are economically unfeasible to completely replace. However, these can be simply modified with cost effective equipment to raise the monitor, keyboard and mouse components to standing height without having to replace existing equipment. Given the successful use of sit-stand workstations to interrupt prolonged sitting and reduce overall sitting time in the workplace (Alkhajah et al., 2012; Straker et al., 2013), these workstations are becoming a useful tool to change workplace sitting behaviours.

Implementation of sit-stand workstations has been shown to prevent the onset of musculoskeletal symptoms in previously asymptomatic participants and periods of standing.
allow for a musculoskeletal recovery period when interspersed with sitting (Karakolis, Barrett & Callaghan, 2016). However, much of the current sit-stand research addressing musculoskeletal complaints is conducted in simulated office environments. This does not accurately represent a sample of the sedentary working population; as confounding variables such as psychosocial stress and recurring or chronic WMSDs are not considered. In many cases of both field and laboratory research using sit-stand workstations, participants are asymptomatic so do not have any pain at baseline. Conversely, the frequency of musculoskeletal discomfort in office workers is high, with point prevalence as high as 93% (Ayanniyi, Ukpai & Adeniyi, 2010). After an initial onset of symptoms, chronicity of pain may develop in up to 27% of office workers with neck pain and 61% of patients with low back pain (Sihawong, Sitthipornvorakul, Paksaichol, Janwantanakul, 2016). Chronic recruitment of smaller motor units over months and years due to prolonged activation in sustained postures without momentary rest causes cumulative injury to muscle fibres and soft tissues, resulting in development of WMSDs. Therefore, many current studies provide some insight into aetiology and prevention of WMSDs but are not relevant to the population in which WMSDs are already being suffered, as there is a cumulative effect in the development of WMSDs. Further research involving sit-stand workstations is necessary, to determine whether alteration of sedentary behaviours results in therapeutic change and addresses current and chronic WMSDs experienced by the workforce.
Chapter 3
SIT-STAND WORKSTATIONS AND WORK-RELATED MUSCULOSKELETAL DISCOMFORT: A CRITICAL REVIEW

An examination of current literature to critically appraise research investigating sit-stand workstations in the workplace with use of musculoskeletal discomfort as an outcome measure
3.1 Introduction

Prolonged sitting has been associated with musculoskeletal discomfort (Bergqvist et al., 1995), and more recently as a metabolic risk factor, with a strong dose-response relationship between sitting time and all-cause mortality (Katzmarzyk et al., 2009). The average adult is sedentary for ~70% of waking hours (Colley et al., 2011), and in the case of people working in offices, more than half of this sedentary behaviour occurs in the workplace (Neuhaus et al., 2014). Therefore, many strategies to reduce overall sitting time are structured around workplace behaviours, and sit-stand workstations are effective at reducing workplace sitting time by displacing it with standing (Alkhajah et al., 2012; Neuhaus et al., 2014; Straker et al., 2013). A sit-stand workstation is a specialised desk that has a single surface that may be used in either a sitting or standing position by altering the surface height (Callaghan, De Carvalho, Gallagher, Karakolis & Nelson-Wong, 2015). The intention of using a sit-stand workstation to decrease sitting is to reduce sedentary behaviour, and increase non-exercise physical activity. As a result, there is a reduction in sedentary risk and morbidity associated with sitting in the workplace.

Sitting time is a modifiable risk factor for musculoskeletal pain and discomfort, including low back pain (Andersson, 1981; Frymoyer, 1980), neck pain (Ariëns et al., 2001), and shoulder and upper limb disorders (Korhonen et al., 2003; Ortiz-Hernández et al., 2003). Whilst the aetiology of musculoskeletal pain is largely multifactorial, prolonged, unbroken bouts of sitting have a negative impact on the development and chronicity of sitting related pain. Increasing the proportion of standing at work has been proposed as a strategy to mediate a reduction in sitting time and promote musculoskeletal and overall health of seated office workers (Karlqvist, 1998). Importantly, predisposing risk factors for the development of work-related musculoskeletal disorders (WMSDs) such as postural stasis and muscular overloading are reduced by improving workstation variation; potentially preventing the development of new or recurring sitting related pain.

A recent systematic review by Karakolis and Callaghan (2014), investigated the impact of sit-stand desks in the workplace on worker discomfort and productivity. The review concluded there is general agreement in the literature that introducing sit-stand workstations in an office environment results in lower levels of reported musculoskeletal discomfort. However, the review identified two areas of interest where the available literature provided unclear evidence: firstly, the sit-stand ratio varied widely amongst the studies and, secondly, there is a lack of consensus as to whether working in the standing position increases hand/wrist discomfort. Karakolis and Callaghan (2014) used a unique quality appraisal tool specifically
designed for appraising sit-stand workstation studies, but did not utilise the resulting quality score to summarise the overall level of evidence across studies. A meta-analysis was not conducted due to methodological diversity and statistical heterogeneity causing results to be unsuitable for statistical pooling, hence why the review is a descriptive interpretation only.

Whilst recently published, Karakolis and Callaghan’s study only includes studies up to the 2009 period. Based on the recommendation of the Cochrane Collaboration, it has been suggested that systematic reviews are updated every two years (Moher et al. 2008). Updating review methods and incorporating new studies allows revision of review findings, as newer data may influence estimates of overall effect and modulate consistency of findings between studies.

Since Karakolis and Callaghan’s (2014) review there has been a substantial amount of interest in sit-stand workstations in the media and amongst researchers. In order to comprehensively evaluate the quality of evidence and gain a thorough understanding of the current research, a new critical review was undertaken to update and inform the impact of sit-stand desks in the workplace on worker discomfort. Therefore, the aim of this chapter was to investigate the effectiveness of sit-stand workstations in reducing worker discomfort. A secondary aim was to summarise the progress that has been made with regard to the critical issues identified by Karakolis and Callaghan (2014) where mixed or inconclusive evidence was present; and identify new issues apparent in recent literature not included by Karakalis and Callaghan (2014).
3.2 Methods

3.2.1 Design

A systematic review was undertaken to assess the effect of a sit-stand workstation as an intervention for musculoskeletal pain and discomfort. Specifically, studies situated in existing or simulated seated office worker environments were included. All studies utilising sit-stand workstations were considered and included if the workstation was used as an intervention and musculoskeletal symptoms were reported as an outcome measure. Karakolis and Callaghan (2014) included productivity as a requisite outcome measure; however, this was excluded from the current review.

3.2.2 Search strategy

The search strategy (Figure 1) was developed and carried out at repeated intervals between 10 May 2013 and 1 June 2016. One investigator conducted database searches and screened article titles and abstract for relevancy to ‘sit-stand workstations’. The principal search syntax was: sit-stand workstation AND discomfort AND office. The reference lists of the articles located were inspected to identify additional related studies. The full text of each relevant article was retrieved and reviewed, studies were excluded where only the abstract was available or the source was not peer reviewed (Harris, Quatman, Manring, Siston & Flanigan, 2014). Studies where musculoskeletal discomfort was not a primary or secondary outcome measure, or where results of outcome measures were not reported in sufficient detail were not eligible for appraisal if there was inadequate methodological detail present to allow for robust appraisal.

3.2.3 Study criteria and selection

Once a relevant list of articles was identified and duplicates removed, articles meeting the following inclusion and exclusion criteria were collated:

1. Primary research study that utilised a sit-stand workstation as the intervention.
2. Participants worked in a simulated or existing office work setting.
3. Outcome measures included a measure of participant subjective musculoskeletal pain or discomfort.
4. Article was published in the English language.
All full text articles satisfying these criteria were further reviewed to confirm the research design and experimental method was described in sufficient detail to allow critical appraisal of methodological quality. Figure 1 shows the flow diagram for search strategy and study selection.

![PRISMA flow diagram of search strategy and study selection](image)

Figure 1. PRISMA flow diagram of search strategy and study selection
3.2.4 Quality appraisal

Appraisal of methodological quality was performed using a modified version of the assessment tool developed by Karakolis and Callaghan (2014), as reported in a recent systematic review on the impact of sit-stand office workstations on worker discomfort and productivity. The original 3-point (0-2) scoring system was based on four components and a high-quality study was one that fully met all the quality conditions (total score of 8/8). The quality appraisal criteria and scoring system is outlined in Table 1.

3.2.5 Modification of the quality appraisal tool

In order to illustrate the differences in study quality, the weighting score was reviewed and altered for the Intervention and Adherence quality measures. Karakolis and Callaghan (2014) assigned a maximum score of 2 to studies that met the Intervention criteria of using a fixed sit-stand ratio or self-selected sitting and standing time, where sitting and standing time were measured and where the sitting condition did not use a high chair. To obtain an Intervention score of 2 it was sufficient to have a measure of sitting and standing time, regardless of the rigour of the measure itself. For the Adherence criteria, where the participant adherence to the sit-stand regime was unclear, a score of 1 was applied. However, in previewing studies there were discrepancies as to how the sitting and standing time was both measured and reported between studies. Self-report questionnaire was a common subjective measure of self-reported sitting and standing as a percentage of the workday; whereas other studies were designed with a mandatory sit-stand ratio where deviation or self-selected sitting/standing time was not permitted. Some field studies instructed participants to use a specific sit-stand ratio but did not measure whether participants adhered to the regime. To capture these differences in sit-stand measurement between studies, scoring of the Intervention and Adherence criteria was altered for the purposes of quality appraisal in this review (Table 1). The modifications allowed for distinction between various levels of rigour for outcome measures and participant adherence to the sit-stand regimes for the studies included, in particular whether the sit-stand component was measure subjectively or objectively.

Changing the Intervention criteria allowed differentiation between the various objective and subjective measures of sitting and standing time; identifying greater stratification of quality than the appraisal of Karakolis and Callaghan (2014). Previous comparisons of self-reported and objective inclinometer-measured physical activity found large discrepancies between the two measures, with participants more likely to over-estimate physical activity in comparison to the objective measure by up to 47% (Dyrstad, Hansen, Holme & Anderssen, 2014). To
differentiate between studies measuring sitting and standing time on a self-reported Likert-type scale and studies that can provide this data objectively in minutes per day, greater weighting was given to studies that measured this item objectively.

Whereas altering the Intervention criteria gave greater insight into the accuracy of the recorded sit-stand time; altering the Adherence criteria differentiates between the disparities in the nature of reporting whether participants adhered to the prescribed standing regime. The Randomisation and Applicability criteria were not altered from that established by Karakolis and Callaghan (2014), as they were considered accurate and appropriate defining scores for analysis. Randomisation and use of a control group contribute to data quality; hence the presence of both components was required to obtain a score of 2, and absence of both components a score of 0. For Applicability, studies performed in the field were given higher weighting than laboratory studies. There was no floor effect for the Applicability criteria, as studies where a score of 0 was appropriate were not included in the review, as they did not meet the inclusion criteria of musculoskeletal discomfort as an outcome measure.
<table>
<thead>
<tr>
<th>Score</th>
<th>Karakolis and Callaghan (2014)</th>
<th>Modification</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>A sit-stand group and at least one control group AND subjects randomly assigned to each group</td>
<td>Participants were either instructed to follow a sit-stand ratio or participants were allowed to self-select time spent sitting/standing and time spent sitting/standing was measured by the experimenter AND sitting condition was not a high chair</td>
</tr>
<tr>
<td>1</td>
<td>No control group OR no randomisation</td>
<td>Time spent sitting/standing was measured subjectively or the method of measuring time spent sitting/standing was not reported OR sit was in a high chair</td>
</tr>
<tr>
<td>0</td>
<td>No control group AND no randomization.</td>
<td>Time spent sitting/standing was not measured OR reported subjectively and sit was in a high chair.</td>
</tr>
</tbody>
</table>

**Intervention**

<table>
<thead>
<tr>
<th>Score</th>
<th>Karakolis and Callaghan (2014)</th>
<th>Modification</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Participants were either instructed to follow a sit-stand ratio or participants were allowed to self-select time spent sitting/standing and time spent sitting/standing was measured by the experimenter AND sitting condition was not a high chair</td>
<td>Participants were either instructed to follow a sit-stand ratio or participants were allowed to self-select time spent sitting/standing and time spent sitting/standing was measured objectively by the experimenter AND sitting condition was not a high chair</td>
</tr>
<tr>
<td>1</td>
<td>Time spent sitting/standing was not measured OR sit was in a high chair</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>Time spent sitting/standing not measured AND sit was in a high chair</td>
<td></td>
</tr>
</tbody>
</table>

**Adherence**

<table>
<thead>
<tr>
<th>Score</th>
<th>Karakolis and Callaghan (2014)</th>
<th>Modification</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Participants strictly followed the instructed sit-stand ratio OR for self-selected studies, alternated between sitting/standing at least once per day</td>
<td>Participants strictly followed the instructed sit-stand ratio OR for self-selected studies, participants alternated between sitting/standing at least once per day and participant adherence was measured objectively</td>
</tr>
<tr>
<td>1</td>
<td>Participant adherence was unclear</td>
<td>Participant adherence was measured subjectively or the measure was not reported AND participants alternated between sitting / standing at least once per day</td>
</tr>
<tr>
<td>0</td>
<td>Participants did not alternate between sitting/standing at least once per day</td>
<td>Participant adherence was unclear OR participants did not alternate between sitting/standing at least once per day</td>
</tr>
</tbody>
</table>

**Applicability**

<table>
<thead>
<tr>
<th>Score</th>
<th>Karakolis and Callaghan (2014)</th>
<th>Modification</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Study conducted in the field (i.e. not a laboratory study) AND at least one outcome variable was discomfort</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Not in the field OR did not have discomfort as an outcome variable</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>Not in the field AND did not have discomfort as an outcome</td>
<td></td>
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</tbody>
</table>
Further to the scored quality appraisal of each individual study, a descriptive analysis was undertaken. The overall quality of the literature was appraised using a levels of evidence approach (Barrett et al., 2014; van Tulder, Furlan, Bombadier, Bouter & Editorial Board of the Cochrane Collaboration Back Review Group, 2003), as displayed in Table 2. Meta-analysis was not attempted, as there was insufficient homogeneity amongst the outcome measures, analysis and reporting of statistics.

As there are no standardised criteria for defining study quality using the appraisal tool, study quality was operationally defined as ‘high’ when a quality score was $\geq 6$ of 8, and ‘low’ based on a quality score of $\leq 5$ of 8. Given that there is no single accepted quality threshold, conclusions regarding study quality are sensitive to the operational definition of study quality. Therefore, analysis was also completed using alternative cut points for a ‘high’ quality study at $\geq 5$ and $\geq 7$ of a possible quality score of 8. Findings were defined to be ‘consistent’ where there was general agreement (defined as 75% of available studies) in a positive, neutral or negative outcome for the appraised studies.

<table>
<thead>
<tr>
<th>Level of evidence</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong</td>
<td>Consistent findings from $\geq 3$ high-quality studies</td>
</tr>
<tr>
<td>Moderate</td>
<td>Consistent findings from at least 1 high-quality and $\geq 1$ low-quality studies</td>
</tr>
<tr>
<td>Limited</td>
<td>Consistent findings in $\geq 1$ low-quality study or only 1 study available</td>
</tr>
<tr>
<td>Conflicting</td>
<td>Inconsistent evidence in multiple studies irrespective of study quality</td>
</tr>
<tr>
<td>No evidence</td>
<td>No studies found</td>
</tr>
</tbody>
</table>

Notes: Definition of high-quality was based on cut-points at $\geq 5 \geq 6$ and $\geq 7$ out of a possible 8 quality score (see Methods).
3.3 Results

3.3.1 Search Results

The previous review by Karakolis and Callaghan (2014) identified seven studies relating to sit-stand workstations and musculoskeletal discomfort, six of which have been included in the current review (Davis et al., 2009; Ebara et al., 2008; Hedge, 2004; Husemann et al., 2009; Nerhood & Thompson, 1994; Roelofs & Straker, 2002). Vink, Konijn, Jongejan & Berger (2009) was included in the Karakolis and Callaghan (2014) review, but was excluded here as the authors did not use a comparable sit-stand paradigm. Participants involved in the Vink et al. (2009) intervention were able to self-select a ‘half-stand’ option in addition to sitting and standing. An additional 10 studies were identified (Figure 1.) as meeting the inclusion/exclusion criteria and all were published since the Karakolis and Callaghan (2014) review. Two studies that met the inclusion/exclusion criteria were excluded from this review. Both Mackey et al. (2015) and Pickens et al. (2016) measured musculoskeletal discomfort using modified versions of the Nordic Musculoskeletal Questionnaire (Kuorinka et al., 1987), however, no results were reported for this outcome measure. The characteristics of the 14 appraised studies included in the review are shown in Table 3.
### Table 3

#### Characteristics of Appraised Studies

<table>
<thead>
<tr>
<th>Study Design</th>
<th>Site</th>
<th>Sample Environment</th>
<th>Intervention</th>
<th>Outcome Measures</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nerhood &amp; Thompson (1994)</strong></td>
<td>Pre-Post Intervention</td>
<td>Field</td>
<td>Postal service workers</td>
<td>Manual adjustable (Sit-Stand counterbalance mechanism added)</td>
<td>Training provided</td>
</tr>
<tr>
<td><strong>Reolofs &amp; Straker (2002)</strong></td>
<td>Counter-balanced Experimental</td>
<td>Field</td>
<td>Bank tellers</td>
<td>3 Conditions: 1. Fixed height sitting 2. Fixed height standing 3. Fixed height standing with high chair to allow sit-stand</td>
<td>Training provided</td>
</tr>
</tbody>
</table>

**Notes:** All measures self-reported. Survey description unclear; statistical analysis unclear.
### Hedge (2004)

Pre-Post Intervention Field  
**N = 53; 33 participants completed the required data**

**Gender = NR**  
**Mean age = NR**

Office workers

<table>
<thead>
<tr>
<th>Conditions</th>
<th>1. Fixed height seated</th>
<th>2. Electric adjustable sit-stand</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>User discretion</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min 1 month per condition</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Musculoskeletal discomfort by body region (rating of none/mild/moderate/severe for each region)

Aggregated data reported on the presence of discomfort (any score above 'none') shows increased prevalence for condition 1, in all 28 body areas.

NR

### Productivity

- **57.5% agree condition 2 assists productivity**
- **20% agree condition 1 assists productivity**
- **NR**

### Time spent standing

- **21% of the workday**

### Subjective sleepiness

Subjective sleepiness reported with the same level in all 3 conditions.

### Ebara et al. (2008)

**Counter-balanced Experimental Lab**  
**N=24**  
**Female = 12**  
**Male = 12**

Undergraduates (n=12, 21.1±1.1) & "aged subjects" (n=12, 62.7±1.6)

<table>
<thead>
<tr>
<th>Conditions</th>
<th>1. Fixed height sitting</th>
<th>2. Fixed height sitting with high chair</th>
<th>3. Fixed height standing with high chair to allow sit-stand</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Alternate periods</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>of 10 min sitting &amp; 5 min standing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ratio 2:1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>150 minutes per condition</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Musculoskeletal fatigue** by body region (VAS)

- Bilateral thigh VAS: Condition 2>Condition 1
- Right wrist/hand VAS: Condition 3>Condition 1

**Sleepiness (VAS)**

Subjective sleepiness increased with time for all 3 conditions.

**NR**

**Sympathetic nerve activity (Heart rate variability)**

- Increased ratio of low:high frequency heart rate variability in condition 3, indicating arousal level is maintained during sit-stand condition.
- The arousal level during conditions 1 and 2 declined rapidly after 20 min and stayed low.

Notes:
- Desk heights were self-adjusted. Methodological detail incomplete. Desk heights varied during each condition and 2 office workers performed the pre- and post-intervention tasks.
- **20° above condition 1, high chair added to condition 1.**
Husemann et al. (2009) 
**RCT Lab** 
N = 60 male 
Mean age = NR (range 18 - 35) 
University students 

**2 Conditions:**
1. Fixed height seated 
2. Electrical adjustable sit-stand 

**1 hour blocks:**
- Condition 1 = 45 min sitting, 10 min other, 5 min break 
- Condition 2 = 30 min sitting, 15 min standing, 10 min other, 5 min break 

**Ratio 2:1** 
Four 1-hour blocks each day (8.30 - 12.30) over 5 consecutive days 

**Physical complaints (Giebener Beschwerdebogen)** 
Sum score of physical complaints lower for condition 2 at each data point 

**Productivity** 
No significant difference 

---

Davis et al. (2009) 
**Counter-balanced Experimental Field** 
N=35 
Female=27 
Male=8 
Mean age = NR 

**Call center** 

**4 Conditions:**
1. Fixed height seated 
2. Fixed height seated with reminder software 
3. Sit-stand 
4. Sit-stand with reminder software 

**User discretion** 
Conditions 2 & 4 had reminder software with a prompt to alternate between sitting and standing every 30 min 

**Ratio 1:1** 
4 weeks per condition (2 weeks break - in & 2 weeks observation) 

**Musculoskeletal discomfort by body region (11-point Likert scale)** 
Discomfort reduced 20% for condition 3 compared to condition 1 

**Productivity** 
No significant difference 

---

Pronk et al. (2012) 
**Interrupted time series Field** 
N=34 
Intervention N = 24 
Female = 96%±0.2 
Mean Age = 38.4±11.4 
Control N = 10 
Female = 80%±0.4 
Mean age = 44.2±11.9 

**Officer workers** 

**2 Conditions:**
1. Fixed height seated 
2. Electrical adjustable sit-stand 

**User discretion** 
Baseline (1 week) without intervention 
Intervention period (4 weeks) condition 2 in place for intervention group only 
Postintervention period (2 weeks) without intervention 

**Musculoskeletal discomfort by body region (11-point Likert scale)** 
Significant decrease in upper back and neck discomfort for condition 2 during intervention (p =0.008); improvement was negated during postintervention (p =0.3) 
No significant difference for other body regions 

**Productivity** 
No significant difference 

---

Notes: Reminder software activated at 30 minute intervals but did not require adjustment; actual sit-stand utilisation not recorded
Workplace sitting time

Significant decrease (66 min/day) sitting time for condition 2 during intervention (p=0.03)

Robertson et al. (2013)
RCT Lab
N= 22 female
Mean age ergonomics trained = 43.2±10.4
Mean age minimally trained = 46.2±12.5

NR

Electric adjustable sit-stand
Training provided to ergonomics trained cohort

2 Cohorts:
1. "Ergonomics trained" - required to stand 5 min per 50 min session on days 7-9 and 20 min per 50 min session on days 10-12. - user discretion for remainder

2. "Minimally trained" - user discretion for entirety

19 8-hour days, of which the first 4 days were orientation

Musculoskeletal discomfort by body region (11-point Likert scale)
Total reported symptoms during 15 day study: Ergonomically trained range 0-30 occurrences per day Minimally trained range 38-130 per day. (p<0.01)

NR

Visual discomfort
2 of 6 visual symptoms significantly worse for minimally trained (p<0.05)

NR

Notes: Both groups symptom free prior to study; none of the minimally trained group used the standing function of their sit-stand desk throughout study

Productivity
1. Quantity faxes
2. Quality faxes
No significant difference
Accuracy = ergonomics trained> minimally trained (p=0.03)

NR

Davis & Kotowski (2014)
Counter-balanced Experimental Field
N=37 Female=29 Male=8
Mean age full time workers=37.3±11.5

Call center
4 Conditions:
1.Fixed height seated
2.Fixed height seated with reminder software
3.Sit-stand 4.Sit-stand with user discretion
Conditions 2 & 4 had reminder software with a prompt to alternate between sitting and standing every 30 min

4 weeks per condition (2 weeks break – in & 2 weeks observation)

Musculoskeletal discomfort by body region (11-point Likert scale)
Significant reduction in discomfort of shoulders, lower back & upper back (p≤0.04)
22% to 46% decrease in discomfort
<table>
<thead>
<tr>
<th>Condition</th>
<th>Workstation Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Fixed height seated</td>
<td>2. Electric adjustable sit-stand</td>
</tr>
<tr>
<td>Alternate between sitting and standing every 30 min</td>
<td></td>
</tr>
</tbody>
</table>

**Postural change (video analysis of workstations)**

*Significant increase in standing for conditions 3 & 4 (p < 0.0001)*

20% increase in standing time

**Musculoskeletal discomfort by body region (Nordic Musculoskeletal Questionnaire)**

*Fewer reports of low back discomfort in condition 2 (p = 0.03)*

No significant difference for other body regions

31.8% reduction in workplace sitting time (p = 0.48)

**Productivity (Health and Work Questionnaire)**

No significant difference

**Fatigue**

1. Individual Strength (CIS20-R) Questionnaire
2. MAF Scale (Global Fatigue Index)

Total fatigue score significantly higher for condition 2 (67.8%) than condition 1 (52.7%) (p < 0.001)

No significant difference

**Controlled Pre-Post Intervention**

*Field N = 45
Female = 34
Male = 11
Mean age = 43.7 ± 10.7*
<table>
<thead>
<tr>
<th>Study</th>
<th>Design</th>
<th>Field</th>
<th>N</th>
<th>Female</th>
<th>Male</th>
<th>Mean age</th>
<th>Endurance</th>
<th>Condition 1</th>
<th>Condition 2</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graves et al. (2015)</td>
<td>RCT</td>
<td>Office workers</td>
<td>47</td>
<td>37</td>
<td>10</td>
<td>38.6±9.5</td>
<td>Dynamic</td>
<td>Fixed height</td>
<td>Manual adjustable (desk attachment to allow sit-stand)</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Gao et al. (2016)</td>
<td>Cross-sectional</td>
<td>Office workers</td>
<td>24</td>
<td>14</td>
<td>10</td>
<td>37.7±10.5</td>
<td>Dynamic</td>
<td>Fixed height</td>
<td>Electric adjustable sit-stand</td>
<td>p=0.02</td>
</tr>
<tr>
<td>Karakolis, Barrett &amp; Callaghan (2016)</td>
<td>Counter-balanced Experimental Lab</td>
<td>University students</td>
<td>24</td>
<td>12</td>
<td>12</td>
<td></td>
<td>Dynamic</td>
<td>Alternate periods of 15 min sitting &amp; 5 min standing</td>
<td>p=0.04; condition 3 had the highest discomfort increase over time</td>
<td></td>
</tr>
<tr>
<td>Condition</td>
<td>Sitting</td>
<td>Standing</td>
<td>Notes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Electric adjustable sit-stand</td>
<td>3. Electric standing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Fixed height</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Fixed height</td>
<td></td>
<td>Lower back discomfort level</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

No significant difference in productivity.

Notes: Methodological detail insufficient to determine whether counterbalance measures were complete.
3.3.2 Quality appraisal

The quality appraisal scoring is shown in Table 4. The mean quality score for the studies reviewed was 5.3 out of a possible 8, comparable to the findings of Karakolis and Callaghan (2014) at 5.8/8. Only one study (Davis & Kotowski, 2014) received the maximum quality score of 8. Of the 14 studies, 9 met the operational definition of ‘high’ quality based on a threshold of ≥ 5 of the possible 8. When the threshold of study quality was increased to ≥ 6/8, six studies were assessed as high-quality, and three studies were of high-quality based on a threshold of ≥ 7/8.

The ‘outcome’ of the appraised studies is described in Table 4 and is defined as the direction of the result. A positive outcome is in favour of reduced musculoskeletal symptoms and negative outcome is in favour of increased musculoskeletal symptoms. Results indicating no change to musculoskeletal symptoms are described as a neutral outcome.

Four studies used self-reported questionnaire as the method of data collection (Gao, Cronin, Pesola & Finni, 2016; Gao, Nevala, Cronin & Finni, 2015; Hedge, 2004; Nerhood & Thompson, 1994) and reported sitting and standing time subjectively as a percentage of the workday. Two studies used variations on ‘experience sampling methodology’ where participants were asked at several random times per day by text message “Tell us what you are doing right now: sitting, standing, or walking?” (Pronk et al., 2012); or recorded in a diary at 15-minute intervals if they were sitting, standing or walking (Graves, Murphy, Shepherd, Cabot & Hopkins, 2015). Both methods are subjective as data were either entirely self-reported in the case of self-report surveys, or required extrapolation to calculate minutes per day based on the assumption that the recorded behaviours were indicative of overall behaviours in the case of experience sampling methodology. In general studies using these methods were appraised as lower quality, as there was insufficient methodological detail regarding the sit-stand behaviour to appraise the Intervention and Adherence criteria. Studies received a score of zero for the Adherence criteria where adherence was unclear.

Other studies followed strict sit-stand ratios under laboratory conditions and therefore an additional measure of sitting and standing time was not required, given that variance from the prescribed ratio was not possible (Ebara et al., 2008; Husemann et al., 2009; Karakolis, Barrett & Callaghan, 2016). Three field studies used software (Davis et al., 2009; Davis & Kotowski, 2014), or a timer (Thorp et al., 2014) activated at 30-minute intervals to prompt participants to change position between sitting and standing. However, neither the software nor timer required a change in position to occur.
## Table 4. Quality Score Results

<table>
<thead>
<tr>
<th>Quality Criteria</th>
<th>a)</th>
<th>b)</th>
<th>c)</th>
<th>d)</th>
<th>Quality Score</th>
<th>Quality Score ≥5/8</th>
<th>Quality Score ≥6/8</th>
<th>Quality Score ≥7/8</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nerhood &amp; Thompson (1994)</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td>Positive</td>
</tr>
<tr>
<td>Reolofs &amp; Straker (2002)</td>
<td>1(^R)</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td>Positive</td>
</tr>
<tr>
<td>Hedge (2004)</td>
<td>2(^{RC})</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>6 , Y , Y</td>
<td></td>
<td></td>
<td></td>
<td>Positive</td>
</tr>
<tr>
<td>Ebara et al. (2008)</td>
<td>1(^R)</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>5 , Y</td>
<td></td>
<td></td>
<td></td>
<td>Negative</td>
</tr>
<tr>
<td>Husemann et al. (2009)</td>
<td>2(^{RC})</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>7 , Y , Y , Y</td>
<td></td>
<td></td>
<td></td>
<td>Positive</td>
</tr>
<tr>
<td>Davis et al. (2009)</td>
<td>2(^{RC})</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>6 , Y , Y</td>
<td></td>
<td></td>
<td></td>
<td>Positive</td>
</tr>
<tr>
<td>Pronk et al. (2012)</td>
<td>1(^C)</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td>Positive</td>
</tr>
<tr>
<td>Robertson et al. (2013)</td>
<td>1(^R)</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>5 , Y</td>
<td></td>
<td></td>
<td></td>
<td>Positive</td>
</tr>
<tr>
<td>Davis &amp; Kotowski (2014)</td>
<td>2(^{RC})</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>8 , Y , Y , Y</td>
<td></td>
<td></td>
<td></td>
<td>Positive</td>
</tr>
<tr>
<td>Thorp et al. (2014)</td>
<td>2(^{RC})</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>7 , Y , Y , Y</td>
<td></td>
<td></td>
<td></td>
<td>Positive</td>
</tr>
<tr>
<td>Gao et al. (2015)</td>
<td>1(^C)</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>5 , Y</td>
<td></td>
<td></td>
<td></td>
<td>Positive</td>
</tr>
<tr>
<td>Graves et al. (2015)</td>
<td>2(^{RC})</td>
<td>1</td>
<td>0</td>
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<td>4</td>
<td></td>
<td></td>
<td></td>
<td>Positive</td>
</tr>
<tr>
<td>Gao et al. (2016)</td>
<td>1(^C)</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td>Positive</td>
</tr>
<tr>
<td>Karakolis, Barrett &amp; Callaghan (2016)</td>
<td>1(^R)</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>6 , Y , Y</td>
<td></td>
<td></td>
<td></td>
<td>Positive</td>
</tr>
</tbody>
</table>

Notes:
- a) randomisation & control; b) intervention; c) adherence; d) applicability
- R= Randomised, C = Controlled
An additional objective measure of real-time position in sitting or standing, such as video footage (Davis & Kotowski, 2014) or an inclinometer (Thorp et al., 2014), was used by two studies. Davis et al. (2009) and Roelofs and Straker (2002) also report that video footage was recorded, but as findings were not reported, it is unclear to what extent participants’ sit-stand behaviour adhered to the 30-minute intervals prescribed in both studies. Robertson et al, (2013) included both mandatory standing and free choice periods where participants could sit or stand at their leisure, though did not report how standing was measured for either condition. These studies were generally appraised as higher quality, as the methodological detail was both more objective and detailed.

3.3.3 Participants

Of the 14 studies identified, five were conducted in laboratory or simulated office environments (Table 3), the remaining studies were field-based studies conducted in existing workplaces. In the case of six studies, the cohort was divided into control and intervention groups (Gao et al., 2016; Graves et al., 2015; Hedge, 2004; Husemann et al., 2009; Pronk et al., 2012; Thorp et al., 2014). Several studies used a counterbalanced measures design to test participants in multiple conditions; however, with the exception of Davis et al. (2009) and Davis and Kotowski (2014) the reported methodological detail was not sufficient to determine whether the counterbalance was complete and therefore these studies (Ebara et al., 2008; Karakolis, Barrett and Callaghan, 2016; Roelofs & Straker, 2002) were not considered to be controlled as the possibility of incomplete counterbalance measures could not be ruled out.

The majority of studies either recruited asymptomatic participants, or, did not report the presence or absence of musculoskeletal symptoms at baseline. Nerhood and Thompson (1994) reported that 50% of participants had moderate or severe discomfort in the low back, neck and shoulders at baseline. Gao et al. (2015), and Graves et al. (2015) both report baseline mean perceived musculoskeletal discomfort using Likert-type scales ranging from 1 (very comfortable) to 5 (very uncomfortable), and from 0 (no discomfort) to 10 (extremely uncomfortable) respectively. Gao et al. (2015) only report the baseline mean of lower limb ‘comfort’ in the intervention group, as this appears to be the only region where a statistically significant change has occurred between baseline and follow-up ($p=0.02$, effect size not reported). Graves et al. (2015) reported the baseline mean of both intervention and control group, however, the discomfort rating was in the low range (range = 1.2 to 2.6 out of a possible 10) for both groups in low back, upper back and neck regions. Difficulties arise when comparing these studies, as the reporting methods differ markedly. In addition, most studies excluded participants if existing musculoskeletal conditions were present. In all
studies musculoskeletal symptoms were measured from an initial baseline of nil symptoms; therefore any reported discomfort were considered as a negative outcome associated with use of the sit-stand intervention. It is important to note that no studies intentionally recruited participants with a known WMSD or sitting related musculoskeletal discomfort, therefore these studies cannot address whether a sit-stand paradigm influences existing musculoskeletal symptoms.

3.3.4 Discomfort as an outcome measure

With the exception of Ebara et al. (2008), all of the studies showed a trend towards reduced musculoskeletal discomfort whilst using a sit-stand workstation compared to use of a standard sitting workstation. Multiple studies found decreases in reported levels of musculoskeletal discomfort overall (Davis et al., 2009; Hedge, 2004; Husemann et al., 2009; Roelofs & Straker, 2002) in addition to low back (Davis & Kotowski, 2014; Nerhood & Thompson, 1994; Thorp et al., 2014), upper back (Davis & Kotowski, 2014; Graves et al., 2015; Nerhood & Thompson, 1994; Pronk et al., 2012; ), shoulder (Davis & Kotowski, 2014; Gao et al., 2015; Graves et al., 2015) and neck pain (Gao et al., 2015; Graves et al., 2015; Pronk et al., 2012). Furthermore, three studies reported statistically significant differences (p<0.05; effect size not reported) for a low combined ‘back’ discomfort score when using a sit-stand workstation compared to sitting (Gao et al., 2016; Karakolis, Barrett & Callaghan, 2016; Robertson et al., 2013).

The use of sit-stand workstations causing increased musculoskeletal discomfort found by Ebara et al. (2008) is negated by all of the other identified studies, which are in favour of decreased musculoskeletal symptoms using sit-stand desks in comparison to sitting. This may be due to the use of high chairs for the sitting element of the Ebara et al. (2008) design, comparing standard sitting, ‘high’ sitting and a ‘high’ sit-stand condition. There was a tendency toward higher discomfort in the high-sit and sit-stand conditions compared to the standard sitting condition. Statistically significant (p<0.05; effect size not reported) increases in discomfort were found in bilateral thighs when comparing standard sitting to ‘high’ sit and in the right forearm and right wrist/hand when comparing standard sitting to the sit-stand condition. As considered previously by Karakolis and Callaghan (2014), this may not be an accurate comparison of a sit-stand workstation to a standard sitting workstation, as the sitting component is different for each condition.

Roelofs and Straker (2002) used similar high stools to Ebara et al. (2008) for the sit condition in their investigation of bank tellers, but found no difference for both lower limb and upper limb discomfort for the sit-stand condition compared to the high-sit only condition, although
there were “strong trends” towards lower total body and back discomfort for the sit-stand condition. There is conflicting evidence surrounding use of a high chair as the sitting component of a sit-stand intervention for musculoskeletal discomfort. The arrangement may not be an accurate reflection of a true sit-stand paradigm as the stool-like high chair differs significantly from a standard office chair used in a fixed height seated arrangement.

When comparing a standard sitting workstation to a sit-stand workstation where the sitting component is the same for each condition (i.e. not a high stool such as that used by Roelofs and Straker (2002) and Ebara et al., (2008)), the literature uniformly supports decreased reported discomfort when using the sit-stand arrangement (Table 4). Nine studies calculated the decrease in reported discomfort as being statistically significant (Davis et al., 2009; Davis & Kotowski, 2014; Gao et al., 2015; Gao et al., 2016; Hedge, 2004; Husemann et al., 2009; Karakolis, Barrett & Callaghan, 2016; Pronk et al., 2012; Robertson et al., 2013; Thorp et al., 2014) although only three studies report the effect size for the magnitude of the difference. Of the remaining studies, one study found the decrease in reported discomfort was not significant (Graves et al., 2015) and the detail of statistical methods described did not permit calculation of significance for the other study (Nerhood & Thompson, 1994).
3.4 Levels of Evidence for Musculoskeletal Discomfort Reduction

3.4.1 Overall musculoskeletal discomfort

Musculoskeletal discomfort was reported as an overall discomfort rating in four studies (Davis et al., 2009; Hedge, 2004; Husemann et al., 2009; Roelofs & Straker, 2002) and there was consistency in a positive direction toward reduced discomfort. Hedge (2004) and Davis et al. (2009) report an overall 20% difference in musculoskeletal discomfort reported when using a sit-stand workstation in comparison to use of a sitting workstation. Both studies report that this difference is statistically significant, however only Hedge (2004) reports the p-value (p=0.027). Roelofs and Straker (2002) report a “strong trend” (effect size not reported) towards reduced overall musculoskeletal discomfort in the sit-stand posture, but this was only statistically significant when compared to standing only (p=0.001), not in comparison to sitting (p=0.102). Husemann et al. (2009) report the median group discomfort score for each survey administered throughout the course of the study. Of the 10 data collection time points, there is a statistically significant difference between sitting and sit-stand groups for four data points (p=0.05, p=0.015, p=0.008, p=0.03), but importantly, no overall statistical significant difference was found.

Based on the four studies, the overall level of evidence for reduction in overall musculoskeletal discomfort when using a sit-stand workstation was ‘strong’ based on application of a high-quality threshold at ≥5 and ≥6 out of a quality score of 8. However, at a ≥7 quality threshold the overall level of evidence was ‘moderate’ (Table 5).

3.4.2 Low back discomfort

Four studies reported statistically significant (all p values ≤0.04) reduced low back discomfort when using a sit-stand workstation in comparison to a sitting workstation (Davis et al., 2009; Davis & Kotowski, 2014; Hedge, 2004; Thorp et al., 2014). The effect sizes were reported as 31.8% by Thorp et al. (2014), and 37% by Davis & Kotowski (2014); with no effect size reported in the remaining studies. The overall level of evidence for reduced low back discomfort when using a sit-stand workstation was ‘strong’ where a quality threshold of at ≥5 and ≥6 was applied; however, at a ≥7 quality threshold the overall level of evidence was ‘moderate’ (Table 5).
3.4.2 Upper back discomfort

A positive effect toward reduced upper back discomfort when using a sit-stand workstation was reported by six studies (Davis et al., 2009; Davis & Kotowski, 2014; Graves et al., 2015; Hedge, 2004; Nerhood & Thompson, 1994; Pronk et al., 2012). Of these, four studies (Davis et al., 2009; Davis & Kotowski, 2014; Hedge, 2004; Pronk et al., 2012) report that this trend was statistically significant \( (p \leq 0.04) \) and only Davis & Kotowski (2014) report the effect size (41%). Nerhood and Thompson (1994) report a 94% percentage difference in reported upper back discomfort but do not report sufficient statistical data to calculate significance of the result, and Graves et al. (2015) report that the outcome was not significant \( (p=0.2) \). Applying a quality threshold of \( \geq 5 \) or \( \geq 6 \) resulted in a ‘strong’ overall level of evidence favouring reduced upper back discomfort when using a sit-stand workstation. However, the overall level of evidence was ‘moderate’ at a \( \geq 7 \) quality threshold (Table 5).

3.4.5 Shoulder discomfort

Reduced incidence of shoulder discomfort was reported by five studies (Davis et al., 2009; Davis & Kotowski, 2014; Gao et al., 2015; Graves et al., 2015; Hedge, 2004) when using a sit-stand workstation in comparison to a sitting workstation. Decreases in shoulder discomfort were identified as statistically significant \( (p \leq 0.024) \) by four studies, the exception being Graves et al. (2015) where the change was not significant \( (p=0.2) \). Of these, the effect size was reported only by Davis and Kotowski (2014) (33%).

The overall level of evidence was ‘strong’ for reduced shoulder discomfort where a quality threshold of \( \geq 5 \) or \( \geq 6 \) was applied, however the overall level of evidence was ‘moderate’ where a quality threshold of \( \geq 7 \) was applied (Table 5).

3.4.5 Neck discomfort

Changes in neck discomfort when using a sit-stand workstation were investigated by five studies (Gao et al., 2015; Graves et al., 2015; Hedge, 2004; Nerhood & Thompson, 1994; Pronk et al., 2012). Nerhood and Thompson (1994) reported a 36% percentage difference in reported neck discomfort but do not report statistical significance of the result. Graves et al. (2015) found the outcome was not significant \( (p=0.2) \). The remaining studies found that the difference in reported neck discomfort was statistically significant \( (p \leq 0.024; \text{effect size not reported}) \), with the exception of Hedge (2004) where the right side of the neck was statistically significant \( (p=0.011) \) but the left side of the neck was not \( (p=0.06) \).
A ‘moderate’ overall level of evidence was identified for reduced neck discomfort when using a sit-stand workstation when applying a quality threshold of $\geq 5$, however, applying a quality threshold of $\geq 6$ or $\geq 7$ resulted in a ‘limited’ overall level of evidence (Table 5).

### 3.4.6 Combined ‘back’ discomfort

The three studies investigating ‘back discomfort’ as an outcome reported statistically significant ($p<0.05$, effect size not reported) improvements in ‘back’ discomfort scores when using a sit-stand workstation compared to sitting (Gao et al., 2016; Karakolis, Barrett & Callaghan, 2016; Robertson et al., 2013). ‘Back’ discomfort is described by Gao et al. (2016) and Karakolis, Barrett and Callaghan (2016) as the bilateral upper and low back. Robertson et al. (2013) report this as a combination “significant back body regions”, inclusive of the low back, upper neck, lower neck, and shoulder. As the results for these anatomical regions were reported collectively, it was not possible to analyse the individual region results nor compare the results to the other studies where an individual region result was reported.

The overall level of evidence was ‘moderate’ for reduced ‘back’ discomfort when using a sit-stand workstation when a quality threshold of $\leq 5$ and $\leq 6$ was applied; however, there was a ‘limited’ level of overall evidence when a quality threshold of $\leq 7$ was applied (Table 5).
<table>
<thead>
<tr>
<th>Levels of Evidence for Musculoskeletal Discomfort Reduction</th>
<th>Quality Threshold</th>
<th>Level of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Musculoskeletal Discomfort</td>
<td>≥5</td>
<td>Strong</td>
</tr>
<tr>
<td></td>
<td>≥6</td>
<td>Strong</td>
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<tr>
<td></td>
<td>≥7</td>
<td>Moderate</td>
</tr>
<tr>
<td>Low Back Discomfort</td>
<td>≥5</td>
<td>Strong</td>
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<td></td>
<td>≥6</td>
<td>Strong</td>
</tr>
<tr>
<td></td>
<td>≥7</td>
<td>Moderate</td>
</tr>
<tr>
<td>Upper Back Discomfort</td>
<td>≥5</td>
<td>Strong</td>
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<tr>
<td></td>
<td>≥6</td>
<td>Strong</td>
</tr>
<tr>
<td></td>
<td>≥7</td>
<td>Moderate</td>
</tr>
<tr>
<td>Shoulder Discomfort</td>
<td>≥5</td>
<td>Strong</td>
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<tr>
<td></td>
<td>≥6</td>
<td>Strong</td>
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<tr>
<td></td>
<td>≥7</td>
<td>Moderate</td>
</tr>
<tr>
<td>Neck Discomfort</td>
<td>≥5</td>
<td>Moderate</td>
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<tr>
<td></td>
<td>≥6</td>
<td>Limited</td>
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<tr>
<td></td>
<td>≥7</td>
<td>Limited</td>
</tr>
<tr>
<td>Combined ‘Back’ Discomfort</td>
<td>≥5</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>≥6</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>≥7</td>
<td>Limited</td>
</tr>
</tbody>
</table>

Notes: ‘Quality Threshold’ refers to number of relevant quality score items being satisfied for definition of ‘high-quality ’ out of a possible 8.
3.5 Levels of Evidence for Other Outcome Measures

3.5.1 Productivity

Multiple studies included in this review reported productivity as an outcome measure (Davis et al., 2009; Davis & Kotowski, 2014; Ebara et al., 2008; Graves et al., 2015; Hedge, 2004; Husemann et al., 2009; Karakolis, Barrett & Callaghan, 2016; Nerhood & Thompson, 1994; Robertson et al., 2013; Thorp et al., 2014). Of these, four reported no significant difference between productivity during sit-stand work compared to sitting work (Davis et al., 2009; Davis & Kotowski, 2014; Husemann et al., 2009; Karakolis, Barrett & Callaghan, 2016).

Pronk et al. (2012) state that self-reported productivity improved by 66% in the participants using the sit-stand workstation. Thorp et al. (2014) reports a “trend” toward improved productivity in favour of the sit-stand workstation based on a near significant change ($p=0.053$). Thorp et al. (2014) reported that the self-reported concentration/focus component of the Health & Work Questionnaire (HWQ) was significantly greater while sitting in comparison to sit-stand work (46%; $p=0.006$). This finding, whilst statistically significant, may not be clinically significant. The HWQ is measured on a 10-point scale for each item, and in the case of concentration/focus result the range between mean result of sitting (3.96) and sit-stand (2.71) is only 1.25 units. As the minimal clinically significant difference has not yet been established for the HWQ, it is possible that a relatively modest change of 1.25 units may fall under the minimal threshold.

Overall, there is ‘conflicting’ evidence regarding the influence of a sit-stand workstation on improved productivity. However, although the evidence is conflicting in relation to improved productivity, it is important to note that no study reported a reduction in productivity.

3.5.2 Sit-stand workstation acceptability

Participant feedback on sit-stand workstations was recorded in a variety of ways. The response from participants was positive, although limited implications may be drawn from the results of a small group of studies reporting this feedback using non-comparable measures.

Self-reported fatigue was measured by Pronk et al. (2012) and Thorp et al. (2014). Both studies report a significantly lower total fatigue score ($p<0.01$) for participants using a sit-stand workstation in comparison to a sitting workstation. Pronk et al. (2012) report Pearson’s correlation coefficient only ($r = 0.44; p = 0.01$). Thorp et al. (2014) report the confidence interval of the 140-point CIS20-R Questionnaire responses for sitting (mean 67.8 (95% CI
58.8 to 76.7)) compared to that of the sit-stand workstation (52.7 (95% CI 43.8 to 61.5); 
p=0.001).

Gao et al. (2015) indicate that the adjustability of the electronically controlled sit-stand 
workstation utilised in their study was rated as good (29.2%) or very good (54.2%) by the 
majority of participants, and satisfaction with the sit-stand workstation was also rated highly 
at 75%. Similarly, Graves et al., (2015) reported that 66% of participants in their study would 
use the sit-stand workstation permanently if it were an option offered by their employer.

As the studies report participant acceptability and feedback in a widely heterogeneous 
manner, the studies cannot be compared for analysis. Therefore, the level of evidence is 
‘limited’.

3.5.3 Ergonomic training

Robertson et al. (2013) investigated the effect of ergonomic training on the use of a sit-stand 
workstation in a simulated data entry situation of 8 hours daily over 15 working days. The 
ergonomic training consisted of a lecture, a slide and video presentation, hands on practice, 
‘ergo-reminders’ throughout the study and allowed the participants to notify the experimenter 
of problems or questions. The ‘minimally trained’ participants were given a brief overview of 
using the sit-stand workstation and chair adjustment but at no point did a participant from this 
group stand. The ‘minimally trained’ participants did not use the standing function of the 
desk at any point throughout the study, so were effectively using the workstation as a standard 
sitting workstation. This cohort was found to have increased reports of musculoskeletal 
symptoms in comparison to the ‘ergonomically trained’ (1351 reported symptomatic 
occurrences compared with 127 throughout the study period) with increased range in severity 
of symptoms also (1.25-7.5 compared with 1.25-3.75 on a 10-point Likert scale).

Similarly, Davis et al. (2009) and Davis and Kotowski (2014) used reminder software to 
notify participants to change between sitting and standing at 30-minute intervals and found a 
small additional reduction of sitting time in comparison with sit-stand workstations alone.

The overall level of evidence for ergonomic training to positively influence the utilisation of a 
sit-stand workstation was ‘strong’ when a quality threshold of ≤5 was applied, however, there 
was a ‘moderate’ level of overall evidence when a quality threshold of ≤6 and ≤7 was applied.


3.6 Discussion

The main aim of this chapter was to critically review the effectiveness of sit-stand workstations in reducing worker discomfort; examine progress made with regard to critical issues identified by Karakolis and Callaghan (2014) and identify new issues apparent in recent literature not included by Karakalis and Callaghan (2014).

In their review, Karakolis and Callaghan (2014) concluded that the literature indicated implementation of a sit-stand workstation will result in lower levels of whole body discomfort without a significant reduction in productivity. Similar results have been found here, inclusive of the additional studies included that have been published since the publication of the Karakolis and Callaghan (2014). Karakolis and Callaghan (2014) also found sufficient evidence to conclude that low back discomfort is positively affected by use of a sit-stand workstation in comparison to a seated workstation. This review found a ‘strong’ level of evidence that overall musculoskeletal discomfort and low back discomfort was positively modulated by use of a sit-stand workstation; a ‘moderate’ level of evidence that upper back, combined ‘back’ and shoulder discomfort was modulated, and a ‘limited’ level of evidence that neck discomfort was modulated. The levels of evidence (Table 2) are determined using an operational definition of ‘high’ quality studies where the quality score was ≥ 6 out of 8 (Table 4). Karakolis and Callaghan (2014) identified two areas where the literature provided mixed evidence: firstly, the sit-stand ratio was widely varied, and secondly, there was a lack of consensus as to whether use of a sit-stand workstation increases forearm and hand/wrist discomfort.

3.6.1 Sit-stand ratio

Similar to the results from Karakolis and Callaghan (2014), the studies included in this review utilise a wide variety of ratios of sitting to standing. This variation can create difficulty implementing strategies to introduce sit-stand workstations into a workplace, as there is no established ratio for optimal sitting and standing time.

Several studies used survey to investigate self-reported sitting and standing time whilst using a sit-stand workstation (Gao et al., 2016; Hedge, 2004; Nerhood & Thompson, 1994) and the resulting self-selected standing time ranges from 21.2% (Hedge, 2004) to 36.5% (Gao et al., 2016). This equates to approximately 100 to 175 minutes per 8-hour working day, an average of 17 minutes standing per hour.
Ebara et al. (2008) selected a sitting to standing ratio of 2:1 (5 minutes standing and 10 minutes sitting per 15 minute interval) for 120 minutes periods during their laboratory study. The authors report this as a limitation as it resulted in participants changing position more frequently than observed in self-selected situations. Participants stood 6 times in the 120 minute study period (equivalent to 24 times per 8-hour working day), whereas other studies have reported an average position change between sitting and standing of 1.5 (Hedge, 2004) and 3.6 (Nerhood & Thompson, 1994) times per 8-hour working day. Comparably, Husemann et al. (2009) also used a ratio of 2:1 (30 minutes sitting and 15 minutes standing per hour), however this was interspersed with 15 minutes of general office work (e.g. faxing, photocopying and shredding) per hour. The intervals utilised by Husemann et al. (2009) are more reflective of the self-selected standing frequency of approximately 17 minutes per hour, so may be more readily acceptable to participants. Karakolis, Barrett and Callaghan (2016) used a 3:1 sit-stand ratio of 15 minutes sitting and 5 minutes standing per 20-minute interval. It was found that 5 minutes of standing was sufficient to almost completely attenuate discomfort that increased over the seated periods, allowing a recovery period for musculoskeletal discomfort. Correspondingly, Robertson et al. (2013) used a variety of mandatory standing periods throughout the study, however the maximum sitting period was 25 minutes with a minimum of 5 minutes standing. Other studies used a 1:1 ratio of sitting to standing, with 30-minute intervals in each position (Davis et al., 2009; Davis & Kotowski, 2014; Roelofs & Straker, 2002; Thorp et al, 2014). This ratio appears to be based on recommendations (Biddle et al., 2010) to reduce sedentary periods to 30 minutes or less due to the associations of uninterrupted sitting with negative health outcomes.

A positive relationship has been identified between prolonged sedentary periods and the risk of Type 2 diabetes and cardiovascular disease (Proper et al., 2011; Stamatakis et al., 2011). Dunstan et al. (2012b) and Healy et al. (2008b) have found a positive effect on metabolic variables when sedentary time is interrupted. Similarly, Henson et al. (2016) found that 5 minutes of standing per 30-minute interval is sufficient to reduce postprandial glucose, insulin and non-esterified fatty acids in women at risk of Type 2 diabetes.

In the interest of both musculoskeletal and cardiometabolic health, it may be pertinent to limit seated periods to intervals of no more than 30 minutes, with a minimum standing period of 5 minutes. Doing so prevents prolonged uninterrupted sitting, a risk factor for musculoskeletal discomfort (WHO, 2003), cardiometabolic risk (Stamatakis et al., 2011) and all-cause mortality (Proper et al., 2011). A standing period improves the metabolic profile and affords a musculoskeletal recovery period, thereby mediating a positive impact on overall health.
3.6.2 Forearm and wrist discomfort

The finding of Ebara et al. (2008) for right forearm and right wrist/hand pain is not reflected in the other reviewed studies that measured musculoskeletal discomfort in this area. Multiple studies identified no significant differences between a sit-stand and sitting workstation for reports of upper limb discomfort (Gao et al., 2015; Gao et al., 2016) or for individually itemised elbow, hand or wrist discomfort (Davis & Kotowski, 2014; Thorp et al., 2014). Other studies found a “trend” toward decreased discomfort for sit-stand workstations in the upper limb generally (Roelofs & Straker, 2002) and in the upper arm, elbow, wrists and hands (Hedge, 2004; Nerhood & Thompson, 1994) although this outcome was only identified as statistically significant by one study (Hedge, 2004).

Wrist posture varies between sitting and standing work positions (Hedge, Jagdeo, Agarwal & Rockey-Harris, 2005). Ebara et al. (2008) allowed participants to self adjust the desk level, leading to the possibility of confounding ergonomic factors if not appropriately adjusted. Furthermore, the forearm and wrist/hand discomfort identified by Ebara et al. (2008) was solely in the dominant side of the participants, suggesting that the right side may have been utilised to a greater degree for the language translation task or was more physically involved in the 12 transitions of the desk between sitting and standing over the experimental session.

Overall, the level of evidence is ‘conflicting’ regarding the finding of increased upper limb discomfort with use of a sit-stand workstation. Given the variety in the description of upper limb areas and the direction of the results, findings were not sufficiently consistent to determine a positive, negative or neutral outcome for the appraised studies.

3.6.3 Quality analysis and impact on overall level of evidence

As a result of the appraisal tool modifications, some studies reviewed here were allocated a different quality score than that allocated by Karakolis and Callaghan (2014). In addition, the quality scores in this review more clearly reflect the rigour of the outcome measures. Studies reporting sitting and standing time as objectively measured ‘minutes per day’ were scored higher than those reporting sitting and standing as a percentage based on self-reported estimates, which have been shown to have high margins of error in comparison to objective measures (Dyrstad et al., 2014). Such differentiation may not have occurred had the quality appraisal tool not been modified.

Quality was operationally defined as ‘high’ where the quality score was ≥ 6 out of 8, which
resulted in 40% of the studies being identified as high-quality. The threshold was an arbitrary allocation of studies into ‘high’ or ‘low’ quality on the basis of a pre-determined quality score. Consideration of the impact of threshold definition by sensitivity analysis shows that by lowering the quality threshold to ≥5 out of 8, or increasing the quality threshold to ≥7/8 generally decreases the level of evidence (as outlined in Table 5).

Due to apparent differences in the reporting and analysis of discomfort between appraised studies, a decision was made to differentiate between ‘overall musculoskeletal discomfort’, combined ‘back’ discomfort, and the remaining individual anatomical areas of upper back, low back, shoulder and neck discomfort. Three studies reported combined ‘back’ discomfort. ‘Back’ discomfort is described by Gao et al. (2016) and Karakolis, Barrett and Callaghan (2016) to include the right and left upper and low back. Robertson et al. (2013) report this as a combination of seven “significant back body regions”, inclusive of the low back and the left and right sides of: upper neck, lower neck, and shoulder. Because the studies using a combined ‘back’ measure reported results collectively, it was not possible to derive results for the individual anatomical areas. Had this been possible, it may have increased the level of evidence, as there would be additional high-quality studies included in the assessment for shoulder and upper back. There would be no change to the levels of evidence for the overall musculoskeletal discomfort, or for low back pain if the combined ‘back’ measure were included in these appraisals.

3.6.4 Selection bias

A comprehensive search strategy was used to identify applicable studies investigating sit-stand workstations within an office environment, however, there is a possibility that some studies may not have been identified. Relevant studies may not have included the keywords used in the search syntax or may not have been published in journals indexed within the databases searched. Furthermore, this review used just one investigator to search and appraise the literature, whereas the minimum standard for a systematic review is two investigators (Harris et al., 2014). Within the scope of this thesis these limitations were difficult to avoid, however, as a result there is an inherent higher possibility of bias related to one reviewer undertaking all search tasks, and a risk of biased assessment.

3.6.5 Clinical implications

Examination of the reported findings shows a statistical change in many instances; however, there was little consideration of clinical significance. For many studies, musculoskeletal discomfort was not the primary outcome, or they were designed with exploratory aims, with
the intention to monitor the nature of musculoskeletal symptoms in response to a sit-stand working paradigm. As a result, the majority of studies measure the presence and severity of musculoskeletal discomfort on a Likert-type scale and the resulting outcome statistics are typically at very low levels on the scale for both intervention and control groups. Many studies show statistically significant change but the magnitude of difference between conditions did not equate to a clinically important difference. For example, three studies report statistically significant results using the Likert-type scales (Davis et al., 2009; Davis & Kotowski, 2014; Pronk et al., 2012), however the range between means for sit versus sit-stand is a maximum of 1.22 units. The minimal clinically important difference representing minimal improvement for a 0-10 numeric rating scale (NRS) of pain intensity is 1 to 1.3 (Cepeda, Africano, Polo, Alcala & Carr, 2003; Salaffi, Stancati, Silvestri, Ciapetti & Grassi, 2004). The NRS is ostensibly the measure that these studies have used to measure severity of musculoskeletal discomfort. As participants with known musculoskeletal disorders or WMSDs have not been recruited, most participants are asymptomatic. Discomfort levels reported are in the range of <3 out of 10 for all participants regardless of intervention or control, so it is less likely that a clinically significant change would occur.

The majority of studies included here were conducted in simulated office environments that only simulate sedentary working conditions. With this approach, confounding variables such as psychosocial stress and recurring or chronic WMSDs are not considered. Participants typically had either very low level pain, or did not have any pain at baseline. Therefore, although these studies may provide some insight into aetiology and prevention of musculoskeletal discomfort, they are not generalisable to WMSD populations.

3.6.6 Stakeholder implications

Current studies show a high correlation of sit-stand workstations with both decreased total sitting time and interruption of prolonged sitting time in the workplace (Straker et al., 2013; Gorman, 2012; Healy et al., 2013). There is strong evidence that sit-stand workstations have a positive effect on reports of musculoskeletal discomfort when compared to standard sitting workstations. Participants involved in previous investigations of sit-stand workstations have reported high levels of acceptability (Graves et al., 2015) and satisfaction (Gao et al., 2015) without a noticeable decrease in productivity (Davis et al., 2009; Davis & Kotowski, 2014; Husemann et al., 2009; Karakolis Barrett & Callaghan, 2016). Economic evaluation of sit-stand capable workstations needs to be considered and no study included any data about this aspect. For potential users of sit-stand desks it is important to note that compared to regular seated workstations, higher purchase and set-up costs are likely. For example, ergonomic
assessment of workstation setup will be required due to the differences between wrist posture between seated and standing work (Hedge et al., 2005), and employees may need ergonomic training in addition to installation of the workstation itself in order to increase the frequency of use (Robertson et al., 2013). Given the positive affect of sit-stand workstations on other health outcomes such as cardiometabolic benefits, as well as musculoskeletal discomfort, it is plausible that net benefits will be seen by employers in the form of reduced sick leave and improved overall worker health and satisfaction but these effects have not been investigated to date.

The response to research findings needs to be commensurate with the level of evidence. Healthcare practitioners may not yet be in a position to recommend use of a sit-stand workstation to patients for modulation of WMSDs or discomfort in general. Studies that have been published thus far are generally completed in laboratory settings or involve workstation installation on a widespread basis within a whole department or organisation. To investigate the practical and clinical utility for sit-stand workstations as an ergonomic intervention for WMSDs further research using sit-stand workstations in symptomatic populations is required.

3.6.7 Recommendations for further research

A limitation of this review is the difficulty comparing statistical results and methodological processes given the diversity across the studies and standards of reporting. It was not possible to define the minimum important difference for the effect size due to limited reporting and lack of data. Effect sizes or magnitude of change were rarely reported and in most cases could not be calculated from published data. For example, some studies only report findings as a graph figure or a table (Davis et al., 2009; Nerhood & Thompson, 1994) or others only report musculoskeletal discomfort measures and results where the outcome is statistically significant (Gao et al., 2015; Robertson et al., 2013). This may be explained by the exploratory nature of most studies. As more studies are published, it is likely that methodological and reporting quality will improve as studies emerge with higher standards.

Discomfort resulting from muscle fatigue and ischemia has been proposed as a precursor to muscle disorders, and hence, WMSDs (Sjøgaard, Lundberg & Kadefors, 2000). Incorporating periods of standing into seated office work has been shown to inhibit development of musculoskeletal pain in asymptomatic subjects (Husemann et al., 2009; Robertson et al., 2013). To date, there has been limited investigation using standing in the workplace to facilitate management or treatment of pre-existing sitting related musculoskeletal pain. It has been identified that workers experiencing work-related
discomfort are more than twice as likely to use the sit-stand feature on a daily basis than pain-free workers (Wilks et al., 2006). In light of the prevalence of WMSDs and the adverse health effects of sitting for extended periods, it is important that further research is conducted to identify whether workplace interventions using sit-stand workstations to reduce sitting time are effective in improving WMSD pain and disability.

3.6.8 Conclusions

The findings of this review support those of the previous review (Karakolis & Callaghan, 2014), where the majority of studies indicate a positive influence of a sit-stand workstation on musculoskeletal discomfort with no significant changes to productivity. There are now additional studies that collectively show a ‘strong’ level of evidence in favour of reduced low back, upper back and shoulder discomfort and a ‘moderate’ level of evidence in favour of reduced combined ‘back’ discomfort with use of a sit-stand workstation. The findings of Ebara et al. (2008) regarding increased forearm and hand/wrist discomfort with use of a sit-stand workstation have largely been negated by later studies, with no further reports of this issue. This highlights the importance of appropriate ergonomic workstation assessment and training, given that ergonomic requirements differ between sitting and standing (Hedge et al., 2005) and training has a large impact on use of the sit-stand function (Robertson et al., 2013). There remains a lack of consensus regarding an optimal sit-stand ratio as identified by Karakolis and Callaghan (2014), however, conclusions may be drawn from other health research regarding reduced bouts of sedentary time to 30 minutes or less (Henson et al., 2016). Further research investigating the therapeutic effect of sit-stand workstations in symptomatic cohorts situated in real-world office-based settings is required.
Chapter 4
METHODOLOGY

An outline and justification of the method choice
Implementation of sit-stand workstations has been positively correlated with increased standing by participants suffering musculoskeletal discomfort, in comparison to those without pain (Wilks et al., 2006). Furthermore, use of a sit-stand workstation has been shown to inhibit the development of musculoskeletal discomfort in asymptomatic participants (Husemann et al., 2009; Robertson et al., 2013) in addition to providing opportunities to break up periods of prolonged sitting with musculoskeletal ‘recovery’ periods in a standing position (Karakolis, Barrett & Callaghan, 2016).

To date, there are a small number of studies effectively applying sit-stand workstations as an intervention tool for WMSDs in symptomatic samples, as reviewed in Chapter 3 of this thesis. Due to the nature of prolonged sitting as a factor contributing to the development of WMSDs, it is necessary to further investigate sit-stand interventions aimed at improving worker health and discomfort by the reduction of sitting time. An RCT would be the most robust research design to explore causal relationships between sit-stand workstations and changes in musculoskeletal discomfort. However, the financial cost associated with the execution of this design type, as well as the appropriate sample size to allow for a control group impact feasibility of carrying out such a study within the constraints of a thesis. Moreover, as the use of sit-stand workstations as a therapeutic tool for the management of WMSDs has little current scientific evidence, the use of an RCT is not yet justified.

Single-case designs allow interventions such as sit-stand workstations to be investigated within real-life contexts, within a similar group of participants undergoing the same intervention over a period of time (Kooistra, Dijkman, Einhorn & Bhandari, 2009). The single-case design allows investigators to consider whether causal relationships exist between the intervention (sit-stand desk) and outcomes of interest (change in WMSD symptom status), as compared to a within-participant control (standard sitting workplace behaviour).

A single-case design is particularly applicable for clinical fields, as there is detailed documentation of the characteristics of cases that are responsive or nonresponsive to the intervention (Kratochwill et al., 2010). Participants act as their own control by comparison of baseline data to the post-intervention data (Kratochwill & Levin, 2014), where the same independent variables are measured repeatedly throughout the study phases (e.g. baseline phase and intervention phase).

Data analysis of a case series design study is primarily focused on clinical importance rather than statistical significance (Kratochwill et al., 2010). Results of each participant are considered individually and displayed in graph format for the purpose of interpreting data.
through visual analysis. Trend, level and variability of data points over time are examined to
determine the existence and magnitude of any relationship between the intervention and
outcome variable (Kratochwill et al., 2010).

Through careful application of repeated, systematic measurement of the outcome variables
before and after implementation of the intervention, investigators using a single-case design
can establish causal inference in addition to recording substantial detail regarding each ‘case’
that will assist development of the research knowledge base within the area of investigation
(Kratochwill & Levin, 2014).
Chapter 5
METHODS

A description of the research method, inclusive of materials, study protocols and data analysis
5.1 Design

This study was designed as a longitudinal investigation into the use of sit-stand workstations to influence the presentation of WMSDs in symptomatic sedentary office workers. A two-phase AB prospective single-case study design was implemented (Kratochwill et al., 2010), where A is the baseline phase and B is the intervention phase. Withdrawal and replication phases were not included in the design due to ethical implications in addition to logistical challenges regarding the movement of workstations.

The study was composed of two phases over a total of 10 to 16 weeks, with an equal distribution of time between each phase (Figure 1). Participants were required to complete the questionnaires on a weekly basis throughout both study phases, in addition to fortnightly data export from an inclinometer.

The baseline phase comprised either an 8-week period (Participants 1 and 2) or a 5-week period (Participants 3-6). Participants were provided with the sit-stand workstation at baseline, however it was not in use during the baseline phase. Participants completed their daily work as usual without any intervention.

The intervention phase commenced in week 9 (Participant 1) or week 6 (Participants 3-6) and ran for the same course of time as the baseline phase, except where participants withdrew. Participants were instructed to increase standing at their own discretion, with the intention to reduce sitting to periods of 30 minutes or less.

5.2 Participants

5.2.1 Recruitment

Six participants were recruited, two from a tertiary education institute and four from a corporate firm in the insurance industry. In both locations, employees of each organisation were emailed notices advertising for prospective interest and were provided with the details of the researcher in order to discuss participation.

5.2.2 Eligibility

Initial eligibility was screened in an interview with the researcher and potential participants were provided an information sheet (Appendix C) and a consent form (Appendix D) at a second face-to-face interview.
5.2.3  **Consent and ethics**

Organisational consent was received from the corporate firm from the Occupational Health & Safety Co-Ordinator. All participants gave written informed consent and the study was approved by the Unitec Research Ethics Committee (UREC 2013-1073).

5.2.4  **Inclusion criteria**

Inclusion criteria were: (1) Presence of self-reported WMSD as measured by the Troublesomeness Grid (TG) (Parsons et al., 2006), and Numeric Rating Scale (NRS), with pain in at least one region that is not less than 2/10 (Szeto et al., 2002) on the NRS scale and occurs at least once per week; (2) Main WMSD complaint is pain in the arm(s), neck-shoulder (not glenohumeral joint) upper back region or lower back region; (3) Self-report of routinely undertaking at least 30 hours sitting in typical working week (excluding out of work time); and (4) aged between 18-55 years.

5.2.5  **Exclusion criteria**

Exclusion criteria were: (1) Self-reported work-related musculoskeletal disorder(s) in more than three regions, is less than 2/10 or more than 8/10 on the NRS scale; (2) Sitting less than 30 hours weekly whilst at work; (3) Undergoing current therapy for a musculoskeletal disorder; (4) Current systemic disease e.g. Rheumatoid Arthritis, Systemic Lupus Erythematosus (due to the effect of systemic inflammation on musculoskeletal pain without work-related involvement); (5) Participant was currently pregnant or planning a pregnancy during the research period; (6) Active circulatory disease or vascular abnormalities in lower limbs (e.g. varicose veins); (7) Scheduled annual leave for more than two consecutive working days during the course of the study.

5.3  **Equipment**

5.3.1  **Actigraph GT3X+**:

Participants were asked to wear a personal accelerometer (Actigraph GT3X+, Actigraph LLC., FL, USA) which objectively measures physical activity and body position. For the purposes of this study it was necessary not only to determine total sitting time while at work in an objective fashion, but also standing time and physical activity and any influence the intervention may have on this over time.
The GT3X+ is a triaxial accelerometer that also contains an inclinometer, detecting whether the wearer is sitting, standing or not wearing the device. The device is worn on a strap attached around the thigh and uses an algorithm to classify counts above 100/min as standing and for counts below 100/min, it uses data from the x, y, and z axes to categorize movement as sitting, lying down or non-wear (Hänggi et al., 2012). Kozey-Keadle, Libertine, Lyden, Staudenmayer & Freedson (2011) compared the GT3X+ to activPAL, a similar instrument that measures the wearer’s activity and differentiates between sitting, standing and stepping. The study compared the findings of both devices with direct observation of the participant behaviour and also investigated whether the 100 count per minute cut point was the most accurate for classification of movement measured by the GT3X. The results indicate a correlation between directly observed sedentary minutes and sedentary minutes detected by the GT3X using the 100 counts/min of $r = 0.62$.

5.3.2 Sit-stand workstation

The intervention involved provision of a workstation that can be used in a sitting or standing position, with the ability to alternate between both positions. The two options utilised were:

a) Replacing the participants’ current desk with a height adjustable (Blake Electric Desk, Fuze Business Interiors Ltd, Auckland, NZ) that was powered by user activated electric motor to alternate between sitting and standing by use of a control button. Participants employed at the tertiary education institute were supplied with this option and the researcher provided the desks. The electrical height adjustable desks were removed at the conclusion of the study.

b) Altering the participants’ existing seated workstation with a modular unit (Meerkat Desk, Meerkat Desk Limited, Auckland, NZ) to raise the height of the computer, keyboard and mouse components in order for the workstation to be at a suitable height for use in a standing position. The arrangement required alternating between positions to be performed manually, by the addition or removal of the modular unit. Participants employed at the corporate firm were provided this option, as it was the standard intervention practice applied by the firm where a standing-capable workstation was required. The modular unit could be retained by the participants at the completion of the study where desired, as it was the property of the employer.

The workstation for all participants was set-up in line with ergonomic principles such as appropriate monitor height and keyboard placement (ACC, 2010). This set-up was reassessed when the participants began to use the workstation at a standing height, at the onset of the
intervention phase. Participants were encouraged to seek assistance from the researcher or Occupational Health & Safety Co-Ordinator if there was a need for further ergonomic assessment or if other functional or technological issues arose.

It is necessary to provide an ergonomic orientation, in addition to basic training on desk use. Robertson et al. (2013) conducted a double cohort study in a sit-stand workstation intervention, comparing desk use between minimally trained and ergonomically trained cohorts. Results indicated that unless participants are taught basic ergonomic principles and the relationship of these to the development of WMSDs, they might not use the standing function of the height adjustable desk and therefore not maximize the potential of the change in workstation variability. The orientation was conducted by the investigator, with the support of the Occupational Health & Safety Co-Ordinator at the corporate site and the research supervisor at the tertiary institute.

The participants also had the option available to use a floor mat made of rubber or gel or a footrest if deemed necessary by the investigators. These ergonomic aids increase variety when changing position and enhance matching of the participant to the environment. The participants were asked to perform their regularly assigned job tasks as they would normally, such as taking phone calls, data entry and transcribing.

5.4 Outcome Measures

5.4.1 Troublesomeness Grid (TG)

The TG is both a discriminative and evaluative measure for the presence of pain in 12 body regions (with a further option for ‘other pains’) in the last month (Parsons et al., 2006). Assessment is via use of a Likert-type scale ranging from ‘no pain experienced’ to ‘extremely troublesome’ for each body region. The authors reported the TG has good face validity as it had high completion rates (95%) and a high level of agreement when compared to the pain mannequin (more than 90%). The test-retest reliability ranged from ICC = 0.8-0.9 over a 1-month period. The authors suggest that those with chronic pain often have pain in different regions; therefore the TG captures the impact and severity of the separate complaints in addition to overall discomfort. This minimizes the questionnaire burden, particularly within a study such as this that is conducted over a long period of time and involves multiple testing of participants.
The TG was used in conjunction with the body picture contained in the Nordic Musculoskeletal Questionnaire (NMQ) (Kuorinka et al., 1987), a discriminative measure for the presence of “trouble” (ache, pain or discomfort) in nine body regions (with further left, right or both options for pain in the shoulders, elbows and hands) in the last week, month and year. The NMQ has been implemented in a wide range of studies evaluating work-related musculoskeletal disorders including populations with sedentary behaviours such as computer mouse users (Cook et al., 2000) and car drivers (Porter & Gyi, 2002). The NMQ questionnaire has not been included in the study due to the need to be concise when repeating questionnaires over a long period of time. For each body region specified where the respondent has confirmed the presence of “trouble”, the NMQ has further questions to stipulate whether the respondent has experienced trouble within the last 7 days or within the last year. Within one question, the TG confirms both location and degree of troublesomeness of the pain or discomfort experienced by the participant, therefore was established as the more specific and concise measure for this study.

Due to the longitudinal nature of this study, the data points were collected weekly, with each week separate to the previous. Further evaluative data were collected for every confirmation of ‘troublesome’ pain or discomfort in a given region. An evaluation of pain frequency and severity over the previous week was also included. Frequency was measured on a 9-point numeric scale of ‘0 episodes’ to ‘8 or more episodes’.

5.4.2 Numeric Rating Scale (NRS)

Severity was measured using the NRS, a subjective measure of pain that uses an 11-point scale consisting of numbers 0 through 10, with 0 labelled ‘no pain’ and 10 ‘worst pain possible’ at the other. The participant was required to select a single number that best represented their pain severity. A comparative study of the NRS, Visual Analogue Scale, Verbal Rating Scale and Faces Pain Scale-Revised found that NRS is the most responsive of the four measures (Ferreira-Valente et al., 2011). An NRS question format was used three times at each data point collection during this study, with one NRS scale each for worst pain level, best pain level and current pain level in the previous week. This was used to measure the severity of the participants’ pain and provide ongoing comparative data representing all three pain descriptors.
5.4.3 Functional assessment

Participants were asked to complete a functional questionnaire dependent on the region of their main complaint on enrolment to the study. The questionnaires were allocated as follows:

a) Participants reporting neck pain as the main complaint were allocated the Northwick Park Neck Pain Questionnaire (NPQ) (Leak et al., 1994)

b) Participants reporting arm, shoulder or hand pain as the main complaint were allocated the DASH Questionnaire (DASH) (Hudak, Amadio, Bombadier & The Upper Extremity Collaborative Group (UECG), 1996)

c) Participants reporting back pain as the main complaint were allocated the Roland Morris Disability Questionnaire (RDQ) (Roland & Morris, 1983)

It has been found that the most meaningful outcome measures for patients with chronic pain are the functional tasks involved in activities of daily life (Carnes & Underwood, 2008). As participant outcome measures are not compared between individuals in this single-case design, only within each individual’s results, different functional assessments can be used to accurately measure this change over time. The questions included in the questionnaires are in reference to the ‘past week’ (DASH), and ‘currently’ (NPQ, RDQ) which is relevant to the discriminative amount of time used for each data collection point in this study. They can also be used as a sensitive measure of change over time in either increased or decreased dysfunction and will accurately reflect any changes in musculoskeletal disability as a result of the intervention.

5.4.3.1 Northwick Park Neck Pain Questionnaire (NPQ)

The questionnaire is specific to neck pain and involves nine questions regarding activities of daily life and to the degree to which the participant’s pain or dysfunction limits these activities (Leak et al., 1994). Each question is answered using a 5-point Likert scale, consisting of numbers 0 through 4. A response of 0 relates to ‘no symptoms or functional disturbance’ and 4 relates to ‘maximal symptoms or functional disturbance’. There is a final status question that allows the comparison of current symptoms compared to the last time the questionnaire was answered.

The test-retest reliability of the NPQ has been reported to be good (ICC = 0.85, CI not reported) (Kose, Hepguler, Atamaz & Oder, 2007) and acceptable internal consistency (Cronbach’s α = 0.8) (Kose et al., 2007; Sim et al., 2006). Sim et al. (2006) also indicate a high level of responsiveness, as Guyatt’s responsiveness statistic was 0.93.
5.4.3.2 DASH Questionnaire
The DASH Questionnaire relates to disabilities of the arm, shoulder and hand. It consists of a 30-item disability and symptom scale regarding the previous week. The items refer to the participant’s ability to perform specific physical activities, the severity of the pain or symptoms and the impact activities of daily life. The score is rated from 0-100 points, with a higher score indicating greater disability. Gummesson et al. (2003) surveyed patients undergoing surgery for musculoskeletal disorders of the upper extremity and found a good internal consistency (Cronbach’s α above 0.9). A 10-point difference is considered the minimal important change. Gummesson et al. (2006) compared the DASH to a shorter 11-item QuickDASH questionnaire. This has a lower burden on the participant, particularly when used frequently throughout the course of a study. The QuickDASH was found to have a higher mean score than corresponding DASH groups by up to 5 points. The difference (95%CI) in area under the ROC curve between DASH and QuickDASH ranged from 0.01 to 0.03 indicating similar ability to discriminate between ‘no change’, ‘somewhat better’ and ‘much better’. The test-retest reliability of the QuickDASH was found to be excellent (ICC=0.96).

5.4.3.3 Roland Morris Disability Questionnaire (RDQ)
The RDQ is a measure of physical function, where participants are asked to agree or disagree with 24 statements specifically qualified with the statement ‘because of my back pain’ (Roland & Morris, 1983). This removes the association of decreased physical function due to other causes. The RDQ is a simple and quickly completed questionnaire and has been found to have fewer incomplete or ambiguous responses than the Oswestry Questionnaire (Stratford et al., 1996). The RDQ focuses particularly on physical function, and as such correlates highly with the physical subscales of SF-36, Quebec Back Scale and the Oswestry Questionnaire (Roland & Fairbank, 2000). Test-retest reliability of the RDQ has been reported with a correlation of 0.88 at one week (Johansson & Lindberg, 1998).
5.5 Administration of Outcome Measures

5.5.1 Self-reported data collection procedure

The outcome measures were administered in the form of an online questionnaire (SurveyMonkey Inc., Palo Alto, CA, USA) distributed on a weekly basis. A webpage link to the questionnaire was distributed by email on a Friday, to effectively capture responses from the ‘last week’, which was the discriminative portion of time referred to in the questionnaires included. To ensure consistency between weeks, the email was issued at a similar time each week to each participant.

At the commencement of enrolment, each participant identified his or her main area of complaint (neck pain, back pain or arm, shoulder or hand pain) and a corresponding functional questionnaire was issued as a component of the survey throughout the study. For identification purposes each questionnaire was uniquely coded both to the individual and the specific week of enrolment in the study, however, the participant received an identical survey each week for the duration of the study.

Participants from the tertiary education site (Participants 1-2) received the first questionnaire at the end of the first sitting week, with subsequent questionnaires issued at the end of each participatory week. Participants from the corporate site (Participants 3-6) received the first questionnaire at the onset of the study on the first day of participation and were asked to complete this in relation to musculoskeletal symptoms the prior working week. The second and subsequent questionnaires for corporate site participants were issued at the end of each participatory week, inclusive of the first week.

5.5.2 Actigraph wear-time procedure

Participants were required to wear the inclinometer device during all working hours to the best of their ability during the entire course of the study. Acceptable wear-time compliance of 90% during working hours has been established previously (Alkhajah et al., 2012; Patton Gorman, 2012). In this way, data representing sitting time and physical activity in the workplace can be measured and any changes during the course of the study may be recorded. The device must be attached to the anterior upper leg (Appendix F) in order to calculate the thigh angle and thus inclination to determine the wearer’s position (Schofield, Quigley & Brown, 2009). Previous studies have tested the GT3X device worn at the participant’s hip (Carr & Mahar, 2012) and some have not specified the location (Kozej-Keadle et al., 2011), which
may explain the mixed accuracy of the device reported. Grant, Ryan, Tigbe & Granat (2006) studied the validity of a similar device worn on the participant’s anterior upper thigh, which also contains an inclinometer and found that the mean discrepancy between the device and observation was 0.19%. The device has also been worn in this same manner and used in a sample of sedentary office workers to determine the efficacy of standing desks in reducing office sitting time (Alkhajah et al. 2012). Santos-Lazano et al. (2012) studied the internal validity of the GT3X and found the intra-class correlation coefficients to be high for all three axes (≥ 0.9), however, they do suggest that the device be constantly worn on the same side of the body to produce consistent results, across all participants and for every measure of the same individual. As such, participants were required to wear the device on the right thigh throughout the study.

5.5.3 Sit-stand procedure

As the aim of the study was to investigate the introduction of the sit-stand desks into a symptomatic sample of sedentary office workers with WMSDs, it was considered important to allow each participant to adjust to standing at their individual pace. Atlas and Deyo (2001) recommend a maximum of 30 minutes sitting for people with low back pain. The frequency of 30-minute periods of sitting has also been used as an outcome measure for evaluating changes in prolonged workplace sitting for other sit-stand workplace interventions (Healy et al., 2013; Patton Gorman, 2012). Standing and moving after 30 minutes of continuous sitting or computer work has also been recommended by Owen et al. (2011) and the National Heart Foundation of Australia (2012). Consequently, the participants in the study were encouraged to work in a standing position for as long as they could comfortably sustain, ad libitum, after a period of no more than 30 minutes sitting. The ultimate goal of each participant was the transition to standing at work on a fulltime, or near fulltime basis. There were no strict guidelines regarding the amount of time that must be spent standing during the workday, as individuals may transition to increased standing at different rates. In addition, there was no restriction as to the limit of time spent sitting. Participants were encouraged to minimize this time but were guided to sit if and when they become tired as a result of standing. As each participant had contact with the researcher each week at the point of data collection, this time was utilised to encourage increased standing and shortened periods of sitting.
5.6 Data Analysis

5.6.1 Data extraction

5.6.1.1 Inclinometry data

Data were extracted from the Actigraph device using Actilife proprietary software (v6.12.1.686 ActiGraph, LLC, Pensacola, FL, USA). The researcher manually collected the device every four weeks, raw data were downloaded and the device returned fully charged the following morning. The process prevented data loss due to lack of charge, however participants were also each provided with a charging cable for the device; to allow occasional charging through their PC via a USB port.

Device output data were transferred to a customised Excel spreadsheet (Excel, Microsoft Corporation, Redmond, WA, USA) to allow the calculation of sitting time, standing time and time spent in moderate to vigorous activity. Raw data were adjusted to include only wear time, which occurred during working hours. As participant hours varied in both days of the week and daily shift time due to shift rotations, a workday was considered to be 9 hours. Data were prepared for analysis using units of minutes per day spent in each activity.

5.6.1.2 Discomfort and functional data

The results from weekly questionnaires were extracted and responses collated into an itemised document for each completed questionnaire and manually transcribed into a custom spreadsheet (Excel, Microsoft Corporation, Redmond, WA, USA). Data were tabulated, and checked before further analysis.

5.6.2 Analysis

Data from both methods of collection were first analysed using the custom spreadsheets. Activity periods shorter than 60 seconds were excluded to reduce potential for random error and identify periods of non-wear. Effect size (Cohen’s $d$) was calculated using the means of the entire baseline period and the mean of the data points collected in the final two weeks of the intervention period. Effect size was interpreted using Hopkins descriptors for effect size (Hopkins, 2000) as outlined in Table 6.
Table 6. Hopkins Descriptors for Effect Size (Cohen’s $d$)

<table>
<thead>
<tr>
<th>$d$</th>
<th>Descriptor</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 0.2</td>
<td>Trivial</td>
</tr>
<tr>
<td>0.2 – 0.6</td>
<td>Small</td>
</tr>
<tr>
<td>0.6 – 1.2</td>
<td>Moderate</td>
</tr>
<tr>
<td>1.2 – 2.0</td>
<td>Large</td>
</tr>
<tr>
<td>2.0 – 4.0</td>
<td>Very Large</td>
</tr>
<tr>
<td>&gt; 4.0</td>
<td>Perfect</td>
</tr>
</tbody>
</table>

Further analysis was conducted using Graphpad Prism v7.0a, GraphPad Software, Inc, La Jolla, CA, USA) for the entire study duration. Single-case design is analysed visually through the plotting of each data point and comparison of linear regression lines between the study phases (Kratochwill et al., 2010). An attempt was made to fit a linear regression line for every graph, although where the $R^2$ value was less than 30% (0.3), the linear fit was considered inadequate for interpretation. In this instance the data were evaluated using visual analysis of variance and through use of the calculated means, standard deviations and effect sizes. Where a linear regression line was established, each phase was compared for changes in trend.

A meaningful change was operationally defined for each outcome measure (Table 7) on the basis of smallest worthwhile change (SWC). In the instance of the TG and symptomatic frequency scales, an established SWC or minimal clinically important difference was not identified in the literature. Both measures used Likert scales as the questionnaire tool and a 1 point difference was therefore operationally defined as the SWC. Clinically, the value of 1 point difference is equivalent to a minimum detectible change in troublesomeness or a change in 1 symptomatic day per week for the TG and frequency scales respectively.

Table 7. Operational Definition of Smallest Worthwhile Change

<table>
<thead>
<tr>
<th>Outcome Measure</th>
<th>Previously Established SWC</th>
<th>Operationally Defined SWC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Troublesomeness Grid (6-point Likert Scale)</td>
<td>Nil</td>
<td>1 point difference (calculated individually for each of 12 body regions)</td>
</tr>
<tr>
<td>Frequency (9-point Likert Scale)</td>
<td>Nil</td>
<td>1 point difference (equivalent to 1 symptomatic day per week)</td>
</tr>
<tr>
<td>Numeric Rating Scale</td>
<td>1 point difference or 15%</td>
<td>1 point difference or 15%</td>
</tr>
<tr>
<td>Northwick Park Neck Pain Questionnaire</td>
<td>25% (Sim et al., 2006)</td>
<td>25% change</td>
</tr>
<tr>
<td>DASH Questionnaire</td>
<td>10 points difference</td>
<td>10 points difference</td>
</tr>
<tr>
<td>Roland Morris Disability Questionnaire</td>
<td>3.5 points difference</td>
<td>3.5 points difference</td>
</tr>
<tr>
<td>ActiGraph GT3X+ Inclinometry</td>
<td>Change in mean of twice the standard error of measurement (standard deviation)</td>
<td></td>
</tr>
</tbody>
</table>
Chapter 6

RESULTS

A presentation of the individual results for each participant using visual analysis to determine phase trend, level and variability
6.1 Participant Recruitment

A total of 13 registrations of interest were received. Initial screening was completed by phone interview, seven people were excluded due to ineligibility of discomfort symptoms and planned annual leave during the study period. The remaining 6 participants were recruited following a second face-to-face interview where the information and consent forms were distributed. A flow diagram of participant enrolment and participation is illustrated in Figure 2 and self-reported participant demographics at baseline are outlined in Table 8.

![Flow diagram of participant enrolment and participation](image)

Figure 2. Flow diagram of participant enrolment and participation
A total of 6 participants were invited to take part in the study, 5 of whom remained in the study to completion. There were differences in how the sit-stand workstation was established in the workplace of each participant due to the variability in the options available at each of the two sites.

Participants 1 and 2 were both employees of a tertiary education institute with lecturing roles, for whom an electrically adjustable sit-stand workstation was available as these could be provided by the researcher. These participants had the electric workstations installed at the commencement of the study in place of their current fixed height seated desk. The height of the desks could be altered using a pair of buttons beneath the desktop that would adjust rapidly at the discretion of the user.

Participants 3 through 6 were employees of a corporate firm in the insurance industry and had primarily administration roles in the call centres. At the corporate site, electronic desks were not readily available due to the poor economy of scale and the expense of transporting the desks to the site from elsewhere by the researcher. As such the corporate participants received a manually modified sit-stand workstation that was the current best practice solution utilized by the firm where health and safety conditions necessitated a standing ergonomic solution.

For the baseline phase, the participants utilized their existing seated workstation. At the commencement of the intervention period, a portable modular unit was provided to raise the height of the monitor, keyboard and mouse whilst exploiting the original desk as the platform to mount the unit. This allowed the participant to use their original desk at an appropriate height for standing. The participant received an ergonomic assessment to determine the appropriate height of the desk and modular unit for use in a standing position. The unit required manual adjustment to change the height of the workstation between sitting and standing, as the arrangement necessitated the equipment to be moved by hand.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Workplace</th>
<th>Age</th>
<th>Height</th>
<th>Weight</th>
<th>Gender</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant 1</td>
<td>Tertiary Education Institute</td>
<td>38</td>
<td>1.72m</td>
<td>85kg</td>
<td>F</td>
</tr>
<tr>
<td>Participant 2</td>
<td>Tertiary Education Institute</td>
<td>35</td>
<td>1.65m</td>
<td>60kg</td>
<td>F</td>
</tr>
<tr>
<td>Participant 3</td>
<td>Corporate Firm</td>
<td>26</td>
<td>1.70m</td>
<td>75kg</td>
<td>F</td>
</tr>
<tr>
<td>Participant 4</td>
<td>Corporate Firm</td>
<td>25</td>
<td>1.80m</td>
<td>95kg</td>
<td>M</td>
</tr>
<tr>
<td>Participant 5</td>
<td>Corporate Firm</td>
<td>28</td>
<td>1.82m</td>
<td>100kg</td>
<td>M</td>
</tr>
<tr>
<td>Participant 6</td>
<td>Corporate Firm</td>
<td>29</td>
<td>1.85m</td>
<td>92kg</td>
<td>M</td>
</tr>
</tbody>
</table>
6.2 Individual Results

6.2.1. Participant 1

Participant 1 is female, age 38 and a lecturer at a tertiary education institution. She reported her main pain or discomfort region as low back at baseline. Additional areas of discomfort were identified in the head, neck, shoulder and upper back as the study progressed. As the participant’s primary complaint was low back discomfort, she was designated the RDQ as the appropriate functional measure to be included in the questionnaire.

Participant 1 received an electric sit-stand desk at the commencement of the study and was instructed to use the desk in the seated position for the initial 8 weeks. The intervention period commenced at week 9 and the participant henceforth had the ability to use the desk in self-administered sitting and standing positions. A total of 16 questionnaires were completed with no missing data. A total of 50 days of Actigraph wear time were captured, with a mean daily wear time of 216 minutes (SD = 114) representing 40% of a nominal 540 min working day. The Actigraph device data were missing for the first week due to failure of the thigh support strap used to mount the device. The participant lost the device in the last stage of the intervention period; as a result the data are also missing for weeks 14 to 16.

A meaningful decrease of overall troublesomeness was noted between baseline (M = 22.3, SD = 8.4) and intervention (M = 11.0, SD = 1.4), which equates to a ‘large’ effect size (d = 1.34) and clinically important change of over 50%.

The participant’s main complaint of low back troublesomeness changed from baseline (M = 3.1, SD = 0.4) to intervention (M = 2.5, SD = 0.7) and this decrease had a ‘large’ effect size (d = 1.77) (Figure 3); however, an operationally defined SWC of 1-point difference was not met. The frequency of episodes increased from 5.5 (SD = 2.2) to 7.0 (SD = 0.0), a change of ‘large’ effect size (d = 1.4) in a negative direction (Figure 3). No significant regression relationship ($R^2 < 0.3$) was detected for troublesomeness or frequency of episodes.

The participant’s secondary complaints of shoulder and upper back troublesomeness showed a meaningful decrease (Figure 3), observing the operationally defined SWC in both instances. A ‘moderate’ effect (d = 1.05) was observed for upper back troublesomeness between baseline (M = 3.3, SD = 1.7) and intervention (M = 1.5, SD = 2.1). No significant regression relationship ($R^2 < 0.3$) was detected for upper back troublesomeness or frequency of episodes. A ‘large’ effect (d = 1.81) occurred for shoulder troublesomeness between baseline (M = 3.1,
SD = 1.7) and intervention (M = 0.0, SD = 0.0). The frequency of shoulder episodes decreased from 4 (SD = 3.0) to 0 (SD = 0.0), which also had a ‘large’ effect size (d = 1.34). The change to shoulder troublesomeness and frequency during the intervention reached the floor measure of troublesomeness due to the presence of no discomfort by the conclusion of the study (Figure 3). A significant regression relationship was observed for shoulder troublesomeness ($R^2 = 0.3$) but was not detected for changes in frequency of shoulder episodes ($R^2 < 0.3$).

‘Trivial’ effect sizes were noted for decreased troublesomeness of headache and neck discomfort ($d \leq 0.2$), however there was an increase in frequency for both areas that had a ‘small’ effect size ($d = 0.5$) in a negative direction (Figure 3). None of the changes to headache and neck troublesomeness and frequency of episodes met the established SWC.

There was an improvement of ‘trivial’ effect size ($d = 0.14$) for ‘worst pain level’ from baseline ($M = 7.6$, $SD = 0.9$) to intervention ($M = 7.5$, $SD = 0.7$) (Figure 4). The change in mean of 0.1 did not meet the established SWC for the 10-point NRS scale. Conversely, ‘best’ and ‘current’ pain levels worsened between baseline (‘best’ $M = 3.4$, $SD = 2.1$; ‘current’ $M = 4.5$, $SD = 2.0$) and intervention (‘best’ $M = 4.0$, $SD = 1.4$; ‘current’ $M = 6.0$, $SD = 0.0$) (Figure 4). The SWC for NRS was met for the negative change in ‘current pain level’.

Following the onset of the intervention period, daily standing time increased and daily sitting time decreased (Figure 5). Total daily sitting decreased from baseline ($M = 222$ minutes, $SD = 14$) to the intervention period ($M = 204$ minutes, $SD = 17.5$). A ‘large’ effect size ($d = 1.28$) was observed. Total daily standing increased from baseline ($M = 14$ minutes, $SD = 9.9$) to the intervention period ($M = 29$ minutes, $SD = 13.6$). A ‘large’ effect size ($d = 1.55$) was observed. No significant regression relationship ($R^2 < 0.3$) was detected for the changes in sitting and standing time.

As the participant mean wear time was less than 4 hours per day, the results are not reflective of a complete workday. The above variations equate to practical changes of reduced sitting by 4.5 minutes per hour and increased standing by 3.75 minutes per hour.
**Figure 3.** Participant 1 Troublesomeness and frequency of episodes
A. Trend of headache troublesomeness and frequency of episodes between baseline and intervention
B. Trend of neck troublesomeness and frequency of episodes between baseline and intervention
C. Trend of wrist/hand troublesomeness and frequency of episodes between baseline and intervention
D. Trend of upper back troublesomeness and frequency of episodes between baseline and intervention
E. Trend of low back troublesomeness and frequency of episodes between baseline and intervention
Figure 4. Participant 1 Numeric Rating Scale and RDQ Score
A. Trend of NRS between baseline and intervention
B. Trend of RDQ score between baseline and intervention
Figure 5. Participant 1 Inclinometry
A. Trend of daily sitting time between baseline and intervention
B. Trend of daily standing time between baseline and intervention
6.2.2 Participant 2

Participant 2 is female, aged 35 and a lecturer at a tertiary education institute. At baseline she reported her main pain or discomfort region as low back. Additional areas of discomfort were identified for neck and shoulder. As the participant’s primary complaint was low back discomfort, she was designated the RDQ as the appropriate functional measure to be included in the questionnaire.

Participant 2 received an electric sit-stand desk at the commencement of the study. On installation, the electrical function of the desk was inactive, as the plug connection was purposefully not installed, the intention of which was to eliminate the possibility of the participant utilizing the standing function prior to the intervention period. The desk was set at a suitable height following an ergonomic assessment by the researcher.

Participant 2 completed the initial 8 weeks of the study, completing seven questionnaires. Data were not submitted for week 2 of the study.

During her 8 week participation, Participant 2 consistently did not wear the Actigraph device after coaching and efforts by the researcher to source alternatives to the thigh support used to mount the device. At the conclusion of the 8 weeks the participant advised she had lost the Actigraph device, and there are no data points from the initial data extractions due to non-wear of the device.

Due to non-compliance of the participant, it was determined that she would not continue to the intervention period of the study and the desk was later returned to the researcher and the participant was reinstated with her original desk. No data were analysed.
6.2.3 Participant 3

Participant 3 is female, age 26 and an employee in a corporate firm in the insurance industry. On enrolment in the study, the participant reported a 2-year history of low back, neck and shoulder pain that she felt was the result of her primarily seated job role. Discomfort was also identified in the wrist and hand region during the intervention period. As the participant’s primary complaint was low back discomfort, she was designated the RDQ as the appropriate functional measure to be included in the questionnaire.

Participant 3 used her current fixed height desk during the initial 5 weeks of the study. At the commencement of the intervention period, the participant was provided with the portable modular unit to raise the height of the monitor, keyboard and mouse whilst utilizing the original desk as the platform to mount the modular unit. This allowed the participant to use her original desk at an appropriate height for standing. The participant received an ergonomic assessment to determine the appropriate height of the desk and modular unit for use in a standing position. The unit required manual adjustment to change the height of the workstation between sitting and standing, as the arrangement necessitated the equipment to be moved by hand.

A total of seven questionnaires were completed with three missing data points for weeks 5, 6 and 7. There were 20 days of Actigraph wear time captured, with a mean daily wear time of 474min \((SD = 96)\) representing 88% of a nominal 540min working day. The Actigraph device data are largely missing for the intervention phase due to eight working days of unplanned leave during weeks 6 and 7, and non-wear of the device during week 9.

A ‘moderate’ effect size \((d = 0.78)\) was observed for negative change favoring increased overall troublesomeness between baseline \((M = 1.3, SD = 1.0)\) and intervention \((M = 2.0, SD = 1.7)\).

The participant’s main complaint of low back discomfort was not troublesome during the study, with discomfort only experienced in the neck, shoulder and hand/wrist areas (Figure 6). A ‘moderate’ effect size \((d = 0.87)\) was observed for neck troublesomeness between baseline \((M = 0.5, SD = 0.6)\) and intervention \((M = 0.0, SD = 0.0)\). A ‘large’ effect \((d = 1.5)\) occurred for shoulder troublesomeness between baseline \((M = 0.8, SD = 0.5)\) and intervention \((M = 0.0, SD = 0.0)\). The frequency of shoulder episodes decreased from 2.3 \((SD = 1.5)\) to 1.0 \((SD = 0.0)\), which had a ‘moderate’ effect size \((d = 0.73)\) and a significant regression relationship \((R^2 = 0.35)\). Neck episodes also decreased from 2.8 \((SD = 3.1)\) to 0.5 \((SD = 0.7)\), which had a
‘moderate’ effect size ($d = 0.83$) and significant regression relationship ($R^2 = 0.38$). These changes did not meet operationally defined SWC of 1 point, as the majority of data points were less than this value.

Wrist/hand discomfort increased in both troublesomeness and frequency during the intervention period ($M = 1.0$ troublesomeness, $SD = 0.0$; $M = 3.0$ episodes, $SD = 0.0$) in comparison to no reports of wrist/hand discomfort during the baseline phase (Figure 6). This complaint became the primary area of trouble for the intervention phase. The operationally defined SWC was met for change in a negative direction of more than 1 point for troublesomeness and frequency. A significant regression relationship was detected for troublesomeness ($R^2 = 0.63$) and frequency of episodes ($R^2 = 0.82$).

The participant consistently rated her ‘best pain level’ using the NRS 0-10 scale as 0.0 throughout the study (Figure 7). ‘Current pain level’ decreased from baseline ($M = 0.8$, $SD = 1.5$) in comparison to the intervention phase ($M = 0.0$, $SD = 0.0$) (Figure 7). A ‘small’ effect size was seen for the change in ‘worst pain level’ between baseline ($M = 2.0$, $SD = 1.4$) and intervention ($M = 1.3$, $SD = 0.7$) (Figure 7). None of the NRS changes met the established SWC of 1 point difference.

Whilst the low back was the participant’s primary area of discomfort, the RDQ functional measure for back pain had a low mean score at baseline ($M = 0.3$, $SD = 0.5$) (Figure 7). As the mean score was less than the established SWC, analysis was not completed for the remaining data.

Following the onset of the intervention period, a negative effect was observed where the participant’s daily sitting time increased and daily standing time decreased (Figure 8). A ‘large’ effect size ($d = 1.36$) was observed for the increase of daily sitting from baseline ($M = 473$ minutes, $SD = 22.84$) to the intervention period ($M = 504$ minutes, $SD = 31.81$). There was also a ‘large’ effect size ($d = 1.36$) for the decrease of daily standing increased from baseline ($M = 57$ minutes, $SD = 20.0$) to the intervention period ($M = 30$ minutes, $SD = 25.9$). These changes did not meet the operationally defined SWC, as the change in mean was not twice the standard deviation. Nevertheless, there was a significant regression relationship for both sitting and standing changes ($R^2 = 0.3$) and 30 minutes per day sitting in lieu of standing may be a clinically undesirable change.
Figure 6. Participant 3 Troublesomeness and frequency of episodes
A. Trend of neck troublesomeness and frequency of episodes between baseline and intervention
B. Trend of shoulder troublesomeness and frequency of episodes between baseline and intervention
C. Trend of wrist/hand troublesomeness and frequency of episodes between baseline and intervention
**Figure 7.** Participant 3 Numeric Rating Scale and RDQ Score
A. Trend of NRS between baseline and intervention
B. Trend of RDQ score between baseline and intervention
**Figure 8.** Participant 3 Inclinometry
A. Trend of daily sitting time between baseline and intervention
B. Trend of daily standing time between baseline and intervention
Participant 4 is male, age 25 and an employee in a corporate firm in the insurance industry. On enrolment in the study, the participant reported a 6-month history of low back pain that began at the onset of his employment in a primarily seated job role. As the participant’s primary complaint was low back discomfort, he was designated the RDQ as the appropriate functional measure to be included in the questionnaire.

Participant 4 utilized his current fixed height desk for the initial 5 weeks of the study and was provided by the employer with the modular unit to raise his monitor, keyboard and mouse at the onset of the intervention period. The participant completed all 10 of the questionnaires administered over the duration of the study. There were 32 days of Actigraph wear time captured, with a mean daily wear time of 474 minutes ($SD = 84$) representing 88% of a nominal 540min working day. Actigraph data are missing for weeks 5 and 10 due to loss of battery charge of the device. The participant’s full time equivalent work schedule was a rotating roster; therefore he did not work fixed weekly shifts and occasionally worked on a weekend day in lieu of a regular workday.

The participant’s overall troublesomeness decreased between baseline ($M = 4.2$, $SD = 1.3$) and intervention ($M = 3.0$, $SD = 0.0$), with a ‘large’ effect size ($d = 1.2$). Whilst the overall change may be small at a mean difference of only 1.2 units, the change in overall troublesomeness was 28%, which may be clinically important.

A change of ‘moderate’ effect size was observed in troublesomeness for the main area of discomfort of the low back (Figure 9). Troublesomeness decreased from baseline ($M = 2.6$, $SD = 0.9$) to intervention ($M = 2.0$, $SD = 0.0$). Frequency of low back discomfort increased from baseline ($M = 6.2$, $SD = 1.8$) to intervention ($M = 7.0$, $SD = 0.0$), equating to a ‘small’ effect size ($d = 0.45$) in a negative direction (Figure 9). No significant regression relationships were identified ($R^2 < 0.3$).

Neck discomfort reduced in both troublesomeness and frequency from the baseline (troublesomeness $M = 1.0$, $SD = 1.0$; frequency $M = 1.4$, $SD = 1.7$) to the intervention phase, where there was a consistent response of 0.0 (Figure 9). The effect size was ‘moderate’ for both measures (troublesomeness $d = 1.0$; frequency $d = 0.84$) and a significant regression relationship was identified for troublesomeness ($R^2 = 0.34$) but not frequency of episodes ($R^2 < 0.3$). However, the change was greater than the established SWC of 1-point for both measures and the endpoint of no discomfort is a clinically desirable outcome.
Ankle/foot discomfort increased in both troublesomeness and frequency from baseline (troublesomeness $M = 0.6$, $SD = 0.9$; episodes $M = 1.8$, $SD = 3.0$) in comparison to the intervention period (troublesomeness $M = 1.0$, $SD = 0.0$; episodes $M = 6.6$, $SD = 0.9$) (Figure 9). The effect size for both outcomes was ‘small’ ($d = 0.45$). Although the change in troublesomeness did not meet the established SWC, the difference in mean frequency was substantially greater than the SWC of 1 point. A significant regression relationship was identified for frequency of episodes ($R^2 = 0.54$).

The participant had a consistent ‘best pain level’ using the NRS 0-10 scale, with a mean of 2.0 throughout the study (Figure 10). ‘Current pain level’ decreased from baseline ($M = 3.0$, $SD = 0.7$) in comparison to the intervention phase ($M = 1.8$, $SD = 0.4$) (Figure 10), a change of ‘large’ effect size ($d = 1.4$) that met the established SWC of 1 point difference. A ‘very large’ effect size ($d = 2.9$) was seen for the change in ‘worst pain level’ between baseline ($M = 3.8$, $SD = 0.4$) and intervention ($M = 2.5$, $SD = 0.7$), which also met the established SWC (Figure 10). Significant regression relationships were identified for ‘worst pain level’ ($R^2 = 0.39$) and ‘current pain level’ ($R^2 = 0.48$).

Whilst the low back was the participant’s primary area of discomfort, the RDQ functional measure for back pain had a low mean score at baseline ($M = 2.4$, $SD = 1.1$) (Figure 10). As the mean score was less than the established SWC, analysis was not completed for the remaining data.

In comparison to the baseline period ($M = 493$ minutes, $SD = 16.8$), a meaningful decrease in daily sitting was observed with a ‘perfect’ effect size ($d = 4.64$) during the intervention period ($M = 414$ minutes, $SD = 30.8$). Furthermore, a ‘perfect’ effect size ($d = 5.7$) was noted for the increase of daily standing from baseline ($M = 39$ minutes, $SD = 13.7$) to the intervention period ($M = 117$ minutes, $SD = 30.2$). The difference in daily sitting of 79 minutes and daily standing of 78 minutes exceeded the change in mean of twice the standard error of measurement (Figure 11) and a significant regression relationship ($R^2 = 0.5$) was identified for both sitting and standing changes.
Figure 9. Participant 4 Troublesomeness and frequency of episodes
A. Trend of low back troublesomeness and frequency of episodes between baseline and intervention
B. Trend of neck troublesomeness and frequency of episodes between baseline and intervention
C. Trend of ankle/foot troublesomeness and frequency of episodes between baseline and intervention
Figure 10. Participant 4 Numeric Rating Scale and RDQ Score
A. Trend of NRS between baseline and intervention
B. Trend of RDQ score between baseline and intervention
Figure 11. Participant 4 Inclinometry
A. Trend of daily sitting time between baseline and intervention
B. Trend of daily standing time between baseline and intervention
6.2.5 Participant 5

Participant 5 is male, age 28 and an employee in a corporate firm in the insurance industry. On enrolment in the study, the participant reported a 3-year history of low back pain following a falling accident that resulted in the fracture of several thoracic vertebrae and ribs. The participant advised that he found his sedentary job role exacerbated the post-injury discomfort in the low back region. As the participant’s primary complaint was low back discomfort, he was designated the RDQ as the appropriate functional measure to be included in the questionnaire.

Participant 5 utilized his current fixed height desk for the initial baseline weeks of the study and was provided by the employer with the modular unit to raise his monitor, keyboard and mouse at the onset of the intervention phase. During the time period of the study, Participant 5 took prolonged periods away from work for personal reasons. As such, the data is intermittent as the participant exhibited poor compliance throughout the study, completing 4 questionnaires of the 10 administered; resulting in two data points in each of the pre- and post-intervention phases of the study. There were 28 days of Actigraph wear time captured, with a mean daily wear time of 486 minutes ($SD = 204$) representing 90% of a nominal 540 min working day. The Actigraph device data are limited for the intervention phase due to 9 working days of unplanned leave during weeks 8 through 10. The participant’s full time equivalent work schedule was a rotating roster; therefore he did not work fixed weekly shifts and occasionally worked on a weekend day in lieu of a regular weekday.

A change of ‘small’ effect size ($d = 0.59$) was noted for overall troublesomeness between baseline ($M = 6.0, SD = 4.2$) and intervention phases ($M = 3.5, SD = 2.1$), however, equates to a clinically important change of 42%.

The main area of complaint was the low back, which under went a change in troublesomeness of ‘moderate’ effect size ($d = 0.7$) from baseline ($M = 2.5, SD = 0.7$) to the intervention phase ($M = 2.0, SD = 0.0$) (Figure 12). A significant regression relationship was identified for low back troublesomeness ($R^2 = 0.43$), though this change did not meet the operationally defined SWC of 1 point. However, the frequency of low back episodes increased from baseline ($M = 2.5, SD = 0.7$) to intervention ($M = 5.0, SD = 2.8$), a change of ‘very large’ effect size ($d = 3.5$) in a negative direction (Figure 12).
Headache and upper back discomfort decreased in troublesomeness from the baseline period (headache $M = 1.0$, $SD = 0.4$; upper back $M = 0.5$, $SD = 0.7$) in comparison to no reports of headache or upper back troublesomeness during the intervention phase (Figure 12). The changes in troublesomeness had a ‘moderate’ effect size ($d = 0.7$). In addition, the frequency of episodes decreased from baseline (headache $M = 1.0$, $SD = 0.0$; upper back $M = 0.5$, $SD = 0.7$) to no episodes of upper back pain during the intervention and fewer episodes of headache ($M = 0.5$, $SD = 0.7$) (Figure 12). These changes in frequency had a ‘moderate’ effect size ($d = 0.7$) for upper back pain and a ‘small’ effect size ($d = 0.5$) for headache. A significant regression relationship was identified for headache troublesomeness ($R^2 = 0.43$) and for upper back troublesomeness and frequency of episodes ($R^2 = 0.43$).

Hip/thigh discomfort was also experienced by the participant, with a decrease of ‘small’ effect size ($d = 0.35$) for troublesomeness from baseline ($M = 2.0$, $SD = 1.4$) to intervention ($M = 1.5$, $SD = 2.1$) (Figure 12). The frequency of hip/thigh episodes did not change between the study phases, with a consistent mean frequency ($M = 2.0$) for both baseline and intervention.

The participant had a consistent mean ‘best pain level’ ($M = 0.0$, $SD = 0.0$) and ‘current pain level’ ($M = 0.5$, $SD = 0.7$) throughout the study, using the NRS 0-10 scale (Figure 13). ‘Worst pain level’ increased from baseline ($M = 1.5$, $SD = 0.7$) in comparison to the intervention phase ($M = 2.5$, $SD = 0.7$), a negative change of ‘large’ effect size ($d = 1.4$) that met the established SWC of 1-point difference (Figure 13).

Whilst the low back was the participant’s primary area of discomfort, the RDQ functional measure for back pain had a low mean score at baseline ($M = 0.5$, $SD = 0.7$) (Figure 13). As the mean score was less than the established SWC, analysis was not completed for the remaining data.

Following the onset of the intervention period, changes of ‘trivial’ effect size ($d < 0.1$) was observed where the participant’s daily sitting time decreased and daily standing time increased (Figure 14). Daily sitting decreased from baseline ($M = 442$ minutes, $SD = 63.6$) to the intervention period ($M = 437$ minutes, $SD = 93.2$). Daily standing increased from baseline ($M = 70$ minutes, $SD = 45.9$) to the intervention period ($M = 72$ minutes, $SD = 69.4$). These changes did not meet the operationally defined SWC, as the change in mean was not twice the standard deviation. No significant regression relationship ($R^2 < 0.3$) was detected for the changes in sitting and standing time.
Figure 12. Participant 5 Troublesomeness and frequency of episodes
A. Trend of low back troublesomeness and frequency of episodes between baseline and intervention
B. Trend of upper troublesomeness and frequency of episodes between baseline and intervention
C. Trend of headache troublesomeness and frequency of episodes between baseline and intervention
D. Trend of hip/thigh troublesomeness and frequency of episodes between baseline and intervention
Figure 13. Participant 5 Numeric Rating Scale and RDQ Score
A. Trend of NRS between baseline and intervention
B. Trend of RDQ score between baseline and intervention
Figure 14. Participant 5 Inclinometry
A. Trend of daily sitting time between baseline and intervention
B. Trend of daily standing time between baseline and intervention
Participant 6 is male, age 29 and an employee in a corporate firm in the insurance industry. On enrolment in the study, the participant reported a 1-year history of upper back pain, primarily related to his sedentary job role but also exacerbated by his participation in competitive ballroom dancing. As the participant’s primary complaint was back discomfort, he was designated the RDQ as the appropriate functional measure to be included in the questionnaire.

Participant 6 utilized his current fixed height desk for the initial baseline weeks of the study and was provided by the employer with the modular unit to raise his monitor, keyboard and mouse at the onset of the intervention phase. The participant had unplanned leave during weeks 3, 6 and 9, resulting in missing questionnaire responses and Actigraph wear time during these periods. The intervention phase was postponed for 1 week because he was absent from work during week 6 and therefore the intervention commenced in week 7. A total of 11 questionnaires were administered throughout the study, with Participant 6 completing 8 of the questionnaires; resulting in four data points in each of the pre- and post-intervention phases of the study. There were 23 days of Actigraph wear time captured, with a mean daily wear time of 444 minutes (SD = 108) representing 82% of a nominal 540min working day. Due to Actigraph device failure, data are missing between days 1 and 28 of the baseline phase.

The overall troublesome decreased from baseline ($M = 12.3$, $SD = 4.4$) to the intervention phase ($M = 5.0$, $SD = 0.0$), which equates to a change of ‘large’ effect size ($d = 1.6$) and a clinically important change of 59%.

The participant’s main area of trouble was upper back discomfort, which decreased in both troublesomeness and frequency from baseline (troublesomeness $M = 2.3$, $SD = 1.7$; episodes $M = 3.3$, $SD = 2.2$) to no symptoms or episodes ($M = 0.0$) during the final two weeks of the intervention phase (Figure 15). The change in troublesomeness had a ‘large’ effect size ($d = 1.3$) and the change in frequency of episodes had a ‘large’ effect size ($d = 1.5$). The operationally defined SWC of 1-point difference was met for the change in both outcomes, with a significant regression relationship (troublesomeness $R^2 = 0.52$; episodes $R^2 = 0.71$) for both outcomes.

Neck discomfort was identified throughout the study, with no change in troublesomeness between baseline and intervention ($M = 2.0$) (Figure 15). However the frequency of episodes decreased from baseline ($M = 2.5$, $SD = 3.3$) to intervention ($M = 1.0$, $SD = 0.0$), equating to
a change of ‘small’ effect size \((d = 0.5)\). The regression relationship for these changes was significant for neck episodes \((R^2 = 3.4)\) but was not significant for troublesomeness \((R^2 < 0.3)\).

Shoulder discomfort decreased in both troublesomeness and frequency from baseline (troublesomeness \(M = 2.3, SD = 1.7\); episodes \(M = 2.5, SD = 3.3\)) to no symptoms or episodes (\(M = 0.0\)) during the final two weeks of the intervention phase (Figure 15). The change in troublesomeness had a ‘large’ effect size \((d = 1.3)\) and the change in frequency of episodes had a ‘moderate’ effect size \((d = 0.75)\). The operationally defined SWC of 1-point difference was met for the change in both outcomes, with a significant regression relationship (troublesomeness \(R^2 = 0.7\); episodes \(R^2 = 0.38\)) for the change between baseline and intervention.

Low back discomfort decreased in both troublesomeness and frequency from baseline (troublesomeness \(M = 1.3, SD = 1.0\); episodes \(M = 1.3 SD = 1.3\)) to no symptoms or episodes (\(M = 0.0\)) during the final two weeks of the intervention phase (Figure 16). The change in troublesomeness had a ‘large’ effect size \((d = 1.3)\) and the change in frequency of episodes had a ‘moderate’ effect size \((d = 0.75)\). The operationally defined SWC of 1-point difference was met for the change in both outcomes, with a significant regression relationship (troublesomeness \(R^2 = 0.74\); episodes \(R^2 = 0.61\)) for the change between baseline and intervention.

A decrease in hip/thigh troublesomeness and frequency of ‘large’ effect size \((d = 1.2)\) was noted from baseline (troublesomeness \(M = 1.5, SD = 1.3\); episodes \(M = 1.0 SD = 0.8\)) to no symptoms or episodes (\(M = 0.0\)) during the final two weeks of the intervention phase (Figure 16). The operationally defined SWC of 1-point difference was met for the change in both outcomes, with a significant regression relationship (troublesomeness \(R^2 = 0.5\); episodes \(R^2 = 0.53\)) for the change between baseline and intervention.

Ankle/foot discomfort increased in both troublesomeness and frequency from baseline (troublesomeness \(M = 0.5, SD = 1.0\); episodes \(M = 0.5, SD = 1.0\)) in comparison to the intervention period (troublesomeness \(M = 2.0, SD = 0.0\); episodes \(M = 3.0 SD = 0.0\)) (Figure 16). The change in troublesomeness had a ‘large’ effect size \((d = 1.5)\) and the change in frequency of episodes had a ‘very large’ effect size \((d = 2.5)\). The operationally defined SWC of 1-point difference was met for the change in both outcomes in a negative direction, with a significant regression relationship (troublesomeness \(R^2 = 0.51\); episodes \(R^2 = 0.68\)) for the negative change between baseline and intervention.
The participant had an improvement in all of the NRS scales (Figure 17), with a significant regression relationship for each NRS measure (‘current’ $R^2 = 0.66$; ‘best’ $R^2 = 0.4$; ‘worst’ $R^2 = 0.41$) between baseline and intervention. ‘Current pain level’ decreased from baseline ($M = 2.3, SD = 1.9$) in comparison to the intervention phase ($M = 0.5, SD = 0.7$), a change of ‘moderate’ effect size ($d = 0.9$) that met the established SWC of 1-point difference. A ‘very large’ effect size ($d = 2.4$) was seen for the change in ‘worst pain level’ between baseline ($M = 4.0, SD = 1.2$) and intervention ($M = 1.3, SD = 0.7$), which also met the established SWC. The improvement in ‘best pain level’ between baseline ($M = 1.0, SD = 1.4$) and intervention ($M = 0.0, SD = 0.0$) was of ‘moderate’ effect size ($d = 0.7$) and met the established SWC change of 1-point difference.

Whilst upper back was the participant’s primary area of discomfort, the RDQ functional measure for back pain had a low mean score at baseline ($M = 0.5, SD = 0.6$) (Figure 17). As the mean score was less than the established SWC, analysis was not completed for the remaining data.

In comparison to the baseline period ($M = 465$ minutes, $SD = 23.3$), a decrease in daily sitting was observed with a ‘moderate’ effect size ($d = 0.6$) during the intervention period ($M = 451$ minutes, $SD = 37.1$). Furthermore, a ‘moderate’ effect size ($d = 0.77$) was noted for the increase of daily standing from baseline ($M = 59$ minutes, $SD = 19.1$) to the intervention period ($M = 74$ minutes, $SD = 35.7$). The difference in daily sitting of 14 minutes and daily standing of 15 minutes did not exceed the change in mean of twice the standard error of measurement (Figure 18) and therefore the operational SWC was not met. No significant regression relationship was identified for the changes of sitting and standing ($R^2 < 0.3$).
Figure 15. Participant 6 Troublesomeness and frequency of episodes
A. Trend of upper back troublesomeness and frequency of episodes between baseline and intervention
B. Trend of neck troublesomeness and frequency of episodes between baseline and intervention
C. Trend of shoulder troublesomeness and frequency of episodes between baseline and intervention
Figure 16. Participant 6 Troublesomeness and frequency of episodes
A. Trend of low back troublesomeness and frequency of episodes between baseline and intervention
B. Trend of hip/thigh troublesomeness and frequency of episodes between baseline and intervention
C. Trend of ankle/foot troublesomeness and frequency of episodes between baseline and intervention
Figure 17. Participant 6 Numeric Rating Scale and RDQ Score
A. Trend of NRS between baseline and intervention
B. Trend of RDQ score between baseline and intervention
**Figure 18.** Participant 6 Inclinometry  
A. Trend of daily sitting time between baseline and intervention  
B. Trend of daily standing time between baseline and intervention
Chapter 7
DISCUSSION

An examination of the study results, evaluation of data and identification of study limitations and recommendations for future research
7.1 Findings

The aim of this study was to identify relationships between the use of sit-stand workstations to reduce office sitting time and the resulting influence on the presentation of WMSDs in symptomatic sedentary office workers. Six symptomatic office workers participated over a total period of 65 weeks. Participants completed 52 questionnaires regarding musculoskeletal symptoms and Actigraph data were collected for 153 working days across 5 participants. Data points are missing in each instance, due to participant unplanned leave, non-compliance and in the case of Actigraph data, loss of battery charge, loss of the device or device failure.

Although the study population was small and limited to single-case design, results indicate that use of sit-stand workstations results in reduced sedentary behaviour that positively influences the musculoskeletal discomfort of sedentary office workers.

At baseline, participants spent 82% to 93% of the workday sitting, slightly more than the established sitting time of 81.8% in office environments established previously (Parry & Straker, 2013). Following the introduction of the sit-stand workstation, workplace sitting and standing time was variable throughout the intervention period. Participant 5 had a negligible increase in standing time of 2 min/day and Participant 3 had a change in a negative direction with a reduction in standing time during the intervention phase of 27 min/day. Participants 1, 4 and 6 had changes in a positive direction, where the minimum increase in daily standing time was 15 min/day and the maximum increase in daily standing time was 78 min/day. Workplace standing almost exclusively replaced sitting time with reductions in sitting time of 14 min/day to 78 min/day.

Overall troublesomeness of all body locations (combined scores for the troublesomeness grid) was reduced during the intervention phase for 5 participants. Improvements in the overall troublesomeness ranged from 20% to 59%, however, the degree of change was not correlated with the extent to which standing behaviour changed. Participants 1, 5 and 6 had modest improvements in standing time of less than 20 minutes per day, yet had the greatest degree of change in overall troublesomeness ranging from 42% to 59%. As demonstrated by Participant 6 it is not necessary to have substantial changes in standing time to observe meaningful positive change in reduced musculoskeletal symptoms. Modest displacement of 15 minutes sitting with standing was sufficient to significantly reduce troublesomeness by 59% ($d = 1.6$) in all known areas of discomfort, at the expense of development of a ‘slightly troublesome’ level of ankle/foot discomfort. Participant 4 had the largest meaningful change in standing time of 78 minutes per day and experienced a change of 29% in overall
troublesomeness. A reduction in standing time was observed during the intervention period for Participant 3, nonetheless overall troublesomeness decreased by 20% despite the negative change in standing.

The discomfort of participant-specific additional symptomatic areas also improved during the intervention phase, with decreases of varied magnitude in troublesomeness and frequency of episodes seen for most reports of discomfort. In fact, each participant experienced at least one symptomatic area becoming symptom free during the intervention phase. All participants experiencing shoulder discomfort ceased to have reports of shoulder troublesomeness and episodes by the conclusion of the intervention phase. This outcome may be due to a postural change in elbow angle or shoulder abduction during sit-stand that is known to influence neck and shoulder WMSDs (Marcus et al., 2002).

All 6 participants identified low back as the primary area of discomfort, which is representative of the prevalence of low back pain in New Zealand office workers (Harcombe & McBride, 2009). Participant 3 did not exhibit any notable low back symptoms throughout the study, as suggested by no reports of troublesomeness or episodes of discomfort in this area. The remaining participants experienced modest improvements in low back troublesomeness, in 50% of cases not meeting the established SWC of 1 point difference. Simultaneously, the frequency of low back episodes increased during the intervention period in all but one participant. Moreover, the NRS rating, a measure of raw discomfort level, changed to relatively small degree in both a positive and negative direction and did not exceed twice the standard deviation for any participant; with the exception of the improvement in ‘worst pain level’ for Participant 4 (Range = 1.3, SD = 0.4). The direction of change favouring more episodes of low back discomfort and minor variations in NRS whilst using a sit-stand workstation, whilst not ideal, is mitigated by the self-reported troublesomeness favouring a positive direction of change and suggests that a sit-stand workstation has a favourable effect on troublesomeness.

Whilst this study was not designed to investigate potential mechanisms of discomfort, one interpretation of these findings is that low back discomfort may not be as amenable to standing as other areas of discomfort, such as in the shoulder or neck. For example, internal disc disruption and age related changes to disc height and zygapophyseal joints may increase compressive loading in a standing position (Hafer et al., 1994; Sehgal & Fortin, 2000). Future studies in this area should investigate rigorous selection and suitability processes to ensure participants with symptoms aggravated by standing are not prescribed a standing
intervention. Furthermore, it may be necessary to identify responders from non-responders, as established in pharmaceutical therapy (Trompet et al., 2015).

Lower body symptoms in the ankle/foot were exacerbated for 2 participants, as indicated by an increase in troublesomeness and frequency of episodes during the intervention phase. One participant also noted wrist discomfort, with troublesomeness and episodes occurring during the intervention phase where there were no reports of symptoms at baseline. These negative changes may be a result of increased time standing due to the alterations in body posture causing fatigue and pooling of blood in the lower extremity (Recek, 2013; Waters & Dick, 2015) and the variation of wrist posture between sitting and standing work positions (Hedge et al., 2005). Negative changes to similar bodily areas have been identified in previous sit-stand research (Ebara et al., 2008), however, the use of a high stool for the sitting component was thought to contribute to the negative results for lower limb discomfort.

The RDQ was used as the functional outcome measure for each participant, as all participants identified low back as the primary area of discomfort. The mean RDQ result was less than 3 at baseline for the majority of participants and below the SWC established for the measure (Ostelo & de Vet, 2005). Results indicate that low back discomfort did not have a large impact on functionality, or alternatively that the measure is not sensitive enough to detect minor fluctuations in functional ability for respondents for low levels of disability.

7.2 Inferences

This study is a preliminary investigation specifically targeted to the response of musculoskeletal symptoms to reduction of sedentary behaviour in the workplace. Use of sit-stand workstations have been shown to reduce sedentary time in call centre workers (Straker et al., 2013). Previous workplace intervention studies (Evans et al., 2012; Gilson et al., 2009) have found similar reductions in sitting time, with modest changes of 15 and 17 minutes. Pronk et al. (2012) found a mean reduction in sitting time of 66 minutes per day, equivalent to 225% decrease; similar results were seen for Participant 4 with a reduction in sitting time of 78 minutes per day or 215% decrease in sitting.

A reduction in sitting time improved musculoskeletal symptoms, as has been demonstrated previously in an intervention time frame of 4 weeks (Pronk et al., 2012). More dynamic postures are hypothesised to reduce musculoskeletal discomfort, as prolonged static postures are known to increase discomfort (Fenety & Walker, 2002). Karakolis, Barrett & Callaghan (2016) measured participants over a short time frame of 60 minutes, but found that 5 minutes
of standing work after 15 minutes of seated work was sufficient to completely attenuate sitting related musculoskeletal discomfort.

An ideal ratio of sitting to standing has been debated (Karakolis & Callaghan, 2014), however a recent consensus statement (Buckley et al., 2015) derived from current evidence recommends that workers with seated occupations should aim for 4 hours per day of standing and light activity in the workplace in order to improve cardiometabolic risk. As participants in the present study did not increase objectively measured standing to this extent, it is not possible to determine whether this amount of standing would have a positive or negative effect on musculoskeletal symptoms. It is also suggested that workers adapting to increased levels of standing could experience musculoskeletal discomfort and/or fatigue (Buckley et al., 2015), which could explain the development of new symptoms identified in the ankle/foot and wrist/hand for participants in this study. Further investigation regarding determination of a phase in period may be required to identify a timeframe for practical adaptation to sit-stand work.

Failure to detect meaningful changes for all of the musculoskeletal outcomes may be the result of the complex multifactorial nature of WMSDs and inability to identify change in the limited timeframe of the study. Low back discomfort did not respond to the extent that other regions of discomfort improved during the intervention phase. The 6 to 8 week intervention duration may not have been long enough to sufficiently identify change exceeding natural variation for low back discomfort. Other influencing elements on WMSD development such as stress, job role factors and mental health were not monitored or adjusted for and it is possible these negated or reduced a beneficial effect arising from the reduction of sitting time. Furthermore, sedentary behaviour outside of the workplace was not accounted for in the study, yet forms a large proportion of total sedentary time (Statistics New Zealand, 2011). Recent research suggests that a alternating between sitting and standing every 30 minutes throughout the workday is sufficient to reduce the incidence of low back discomfort by ~30% compared to seated workers (Thorp et al., 2014). Given the relatively small increases in workplace standing found in this study, a greater amount of standing may be required for some WMSDs or some participants to experience pronounced changes.

The consistency of the change in sedentary behaviour was indeterminate, with time spent standing varying throughout the intervention phase for Participants 1, 3 and 5. Participant 6 maintained a consistent level of standing during the intervention phase and Participant 4 displayed a pattern of increasing standing time each week during the intervention phase. More permanent behaviour modification could not be identified as this may require longer
monitoring to ascertain a plateau effect and determine participant maintenance of minimising sedentary behaviour in the workplace.

7.3 Limitations

In order to contextualise results, the following limitations must be acknowledged. Successful interpretation of prospective single-case designs requires sufficient data points, low variance and high compliance from participants in order to make generalisations from results. Whilst the majority of participants completed the minimum requirement of three data points in each phase (Kratochwill et al., 2010), compliance was inconsistent and there was a high level of variability in results. Furthermore, caution must be exercised when drawing inferences from musculoskeletal change associated with small changes in objectively monitored standing time.

Factors contributing to musculoskeletal discomfort are in no way limited to sedentary behaviours and variability of symptoms has been established previously (Josephson, Lagerström, Hagberg & Hjelm, 1997). A high occurrence of symptom variability was noted for participants during the baseline phase, therefore even where the effect size of change is ‘large’, such changes may still be within the range of variability. The minimum clinically important difference for the NRS for pain intensity is 1 point change on the scale or 15% improvement in comparison to the baseline pain severity (Salaffi at al., 2004), however, it is also suggested that an initial baseline response of 3 or less out of 10 will result in greater variability of change in response (Farrar, Pritchett, Robinson, Prakash & Chappell, 2010). This is hypothesized to be a result of limited ability to change (Farrar et al., 2010) or that the minimum clinically important difference increases at higher baseline levels (Katz et al., 2015), suggesting that respondents with lower degrees of pain are more sensitive to change. The mean baseline worst pain level for the majority of participants was 4 or less, indicating a higher potential for natural variability in the responses.

Given the association of psychosocial stressors with the workplace and contribution of the stress response to the experience of WMSDs (Calnan, 2002), the influence of these factors on outcome variables cannot be excluded. Due to the exploratory nature of the study, a measure of job strain or personal stress was not included in order to reduce the participant burden of data collection, such information may be useful in future studies.

The participant burden was considerable throughout the study and no incentive was offered beyond altruistic involvement. Particularly during the intervention phase, participants were
not only expected to change their work practices by altering sedentary behaviours but also to wear the Actigraph device daily and complete a questionnaire on a weekly basis over an extended period of time. The dual level of compliance and the associated burden may be the cause of repeated issues with noncompliance experienced throughout the study. Participant 2 withdrew from the study having failed to wear the Actigraph device correctly and finally having lost the device during the baseline phase. Completion of measures and consistent Actigraph wear time were sporadic for some participants due to unplanned leave and non-compliance. Participant 3 in particular had 8 days of unplanned leave within a 2-week period during the intervention phase and did not wear the device consistently thereafter, resulting in only 6 device wear days during the intervention phase. Acceptable device wear time compliance of 90% of working hours has been established previously (Alkhajah et al., 2012; Patton Gorman, 2012). Only Participant 5 met this wear time compliance when data were standardised to the nominal 540 min working day, with the remaining participants ranging from 40% to 88% wear time. However, had a 480 min working day been the standardised workday as described elsewhere (Alkhajah et al., 2012), 4 participants would have a wear time compliance of ≤ 90%.

Actigraph device failure and battery depletion also resulted in some missing inclinometry data. Participants were provided charging cables and were advised of manufacturer specifications for charging, however, it was observed there was a tendency to store the device in a secure location overnight and not left charging visibly in the workspace. Device failure and battery depletion were not always identified immediately due to the 4-week interval between data extractions. Battery depletion was the cause of 10 working days of missing data and device failure of 20 working days of missing data.

The Actigraph data are a crucial component used to determine the degree of change in sedentary behaviour, the independent variable for the study. Failure to determine this correctly causes difficulty interpreting the musculoskeletal outcome measures and accurately identifying relationships between the variables. Statistically, Participant 3 showed a decreased mean standing time during the intervention phase. However, questionnaire responses indicate a generally positive outcome of reduced musculoskeletal discomfort during this time and the participant was observed working in a standing position frequently by the researcher. It is possible that standing time did improve during the intervention phase, but was not accurately portrayed in the limited device wear time.
7.4 Recommendations

Results of this study support current literature that use of a sit-stand workstation may reduce the incidence of self-reported musculoskeletal discomfort in comparison to a seated workstation (Davis & Kotowski, 2014; Husemann et al., 2009). The findings of this study indicate there is sufficient evidence to justify further research investigating the use of sit-stand workstations to modify sedentary behaviour in the workplace and examine the effect on musculoskeletal symptoms. Although the changes in objectively measured standing time were marginal in some instances, there is a sound basis of research to generate a firm hypothesis that decreasing sitting time may positively influence musculoskeletal discomfort in office workers.

Recommendations for future studies involve amendments to study design, size, duration and data collection. A randomised controlled study over a longer time frame, with use of a larger sample size and similar cohorts would allow for improved rigour of adherence to data collection. A larger sample containing a control group may allow for identification of natural variance in musculoskeletal symptoms in comparison to mediation of symptoms through alteration of sedentary behaviour. It might first be necessary to identify subgroups of participants experiencing musculoskeletal discomfort due to a similar underlying cause, in addition to responders or non-responders to standing intervention; as previous literature has determined that subclassification is required to reveal differences between low back pain patients (Astfalck et al., 2010; Sheeran et al., 2012).

Increased breaks in sedentary time, such as standing up for 5 minutes, have been associated with improvement of cardiometabolic markers (Henson et al., 2016) and attenuation of sitting related discomfort (Karakolis, Barrett & Callaghan, 2016). However, prolonged standing also results in development of non-desirable physiological responses, such as fatigue related WMSDs (Waters & Dick, 2015) and failure of the venous muscle pump due to lack of contracture in the calf muscle (Recek, 2013). Future studies should investigate an optimal ratio of sitting to standing time in the workplace that informs public health interventions aimed at the improvement of cardiometabolic health without detriment to musculoskeletal health.

Future researchers should consider the participant burden and the influence of non-compliance on data collection and analysis. For example, remote monitoring of the height or position of the electronically controlled sit-stand workstation will provide an objective measure of sitting and standing time without requiring participant involvement. A pressure
mat on the seat pan has been used in previous studies of occupational sitting (Zemp et al., 2016) and may also be an alternative to measuring sitting time, in combination with the use of telephone AUX codes used by call centre workers to indicate their work status as available, or away from the workstation. By extension of the study timeframe, questionnaire distribution could also be extended to fortnightly whilst including additional measures of stress and psychosocial health to capture more in-depth data regarding musculoskeletal symptoms and WMSDs.

7.5 Conclusions

WMSDs are multifactorial by nature and consideration of the biopsychosocial model is required to ensure adequate clinical management and approach to research investigations. Sedentary behaviour is a key factor contributing to WMSDs that may be adapted, reduction of which also has a strong positive influence on risk factors for cardiometabolic and overall health risk. Participants involved in this study had mild to moderate work-related musculoskeletal discomfort that responded in a predominantly positive direction to increased standing. Standing aggravated discomfort in the lower extremity and hand/wrist areas for some participants, prompting the requirement for further investigation into a phase-in period or adaptation requirements for standing. If sit-stand workstation use is maintained or improved over longer time periods, standing-mediated health benefits may be recognised for the larger working population. Future research should determine whether workplace sitting may be sustainably reduced through use of a sit-stand workstation and identify an ideal ratio of sitting to standing that further improves both WMSD symptoms and cardiometabolic health.
REFERENCES


Appendix A. Ethics Approval Letter A

Whitney Ferguson
104 Carrington Road
Mount Albert
Auckland

21.11.13

Dear Whitney,

Your file number for this application: 2013-1076
Title: The effect of a standing intervention on musculoskeletal disorders in a sedentary office worker population: A time series design.

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

Start date: 20.11.13
Finish date: 20.11.14

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 Whalley
Deputy Chair, UREC

cc: Rob Moran
Cynthia Almeida
Appendix B. Ethics Approval B

Whitney Ferguson
104 Carrington Road
Mount Albert
Auckland

21.5.15

Dear Whitney,

Your file number for this application: 2013-1076
Title: The effect of a standing intervention on musculoskeletal disorders in a sedentary office worker population: A time series design.

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

Start date: 13.5.15
Finish date: 13.5.16

Please note that:

1. The above dates must be referred to on the information AND consent forms given to all participants.

2. You must inform UREC, in advance, of any ethically-relevant deviation in the project. This may require additional approval.

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

Yours sincerely,

Sara Donaghey
Deputy Chair, UREC

cc: Rob Moran
Cynthia Almeida
Appendix C. Participant Information Sheet

Information for Participants

The effect of a standing intervention on musculoskeletal disorders in a sedentary office worker population: A time series design

This research will be used by principal researcher Whitney Ferguson as part of her Master of Osteopathy degree.

This Participant Information Sheet tells you about the research project. It explains the questionnaires and intervention involved. Knowing what is involved will help you decide if you want to take part in the research.

Please read this information carefully. Ask questions about anything that you don’t understand or want to know more about. Before deciding whether or not to take part, you might want to talk about it with a relative, friend, your employer or doctor.

Participation in this research is voluntary. If you don’t wish to take part, you do not have to.

If you decide you want to take part in the research project, you will be asked to sign the consent section. By signing the consent form you are telling us that you:

• Understand what you have read
• Consent to taking part in the research project
• Consent to completing the questionnaires and interventions that are described
• Consent to the use of your personal and health information as described

You will be given a copy of this Participant Information and Consent Form to keep.
Project Background
In the last century, people have begun to spend increased amounts of time sitting – at work, school, home and public places; causing less movement and more sedentary activity. The recent shift to more sedentary lifestyles has occurred in a short time span and as such, human bodies are not well adapted to a sedentary environment.

Recent research shows us that people who work in sedentary environments have increased rates of work related pain and/or disability. Standing workstations may be useful in changing the amount of sitting time in the workplace.

What we are doing
This project aims to reduce the amount of time spent sedentary in the office by asking participants to use a standing desk in place of their usual desk.

What it will mean for you
Your participation in this research will mean a change in the way you work. The study takes place over a 9-week period. During the first 4 weeks, you will retain your regular desk arrangement. For the following 5 weeks, we will provide you with a standing desk at your workstation. Instead of sitting for the whole day, we will ask you to stand up as often and as long as you are able. In order to achieve this, we suggest that if you need to sit, this is limited to a maximum of 30 minutes at a time. We will also supply you with a small device to wear on your thigh (see picture below), which will allow us to measure how much you stand during your day whilst at work and at home. At the end of the trial you will be required to return the thigh-worn device, however, you may continue to use the standing desk set-up as desired.

What else is involved?
Each week over the 9-week study we will ask you to complete a short questionnaire of 10-15 minutes duration. These will ask questions regarding any pain you are experiencing or difficulty functioning at work due to discomfort. These questionnaires will be sent by email. The only people who will see your answers will be the researchers.

How using a sit-stand desk might affect you
It is common when adjusting to new positions or activities to feel some discomfort. This is a normal response. To reduce discomfort it is recommended that you wear good quality, comfortable shoes to work, as you will be standing for long periods of time. It is expected that you may need to gradually increase the amount of time spent standing initially, with the aim to spend the majority of your working hours standing and minimal
time spent sitting. We will be in contact with you regularly to offer guidance and look forward to answering any queries you may have.

What will happen to your information
All information collected from you will be stored on a password-protected computer. 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.

What if you choose to withdraw
If you decide to withdraw from the study, please notify a member of the research team before you withdraw. This notice will allow the researchers to discuss any issues or special requirements you may have prior to withdrawal. If you withdraw, we will not collect additional personal information from you, although personal information already collected will be retained to ensure the results of the study can be measured properly. Any data collected up to the time you withdraw will form part of the research project results. You can only withdraw up until all the data has been collected. If you do not want this to occur, you must inform us prior to joining the study.

Who to contact
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 my supervisor:

My research supervisor is Robert Moran
Tel: 09 815 4321 ext.8197 or 021 073 9984
Email rmoran@unitec.ac.nz

UREC REGISTRATION NUMBER: 2013-1076
This study has been approved by the UNITEC Research Ethics Committee from 20 November 2013 to 13 May 2016. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the UREC Secretary (ph: 09 815-4321 ext 6162). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.
Appendix D. Participant Consent Form

Participant Consent Form

The effect of a standing intervention on musculoskeletal disorders in a sedentary office worker population: A time series design

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

I understand that this 9-week project will occur in two phases. In the first 4 weeks I will sit at my regular desk after which point I will be supplied with a stand that will raise my keyboard and monitor to allow me to stand at my desk. For the next 5 weeks I will be asked to stand as much as possible while performing my normal daily tasks at work, and may sit for periods that are preferably 30 minutes or less if I wish to. I also understand that I will be asked to wear a small device (about the size of a match-box) on my thigh each day, every day, which will measure how much movement I am undertaking. I consent to a short informal face-to-face debrief with the researcher 2 weeks after the conclusion of the project.

I consent to completing weekly questionnaires during this project to evaluate how I am feeling.

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 not suffered a stroke or a deep vein thrombosis (‘blood clot’).

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 withdraw, 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 of my data upon my written request.

At the end of the study I agree to return all equipment supplied, including the thigh-worn movement device. My employer provides the stand that raises the height of my keyboard and monitor and I can continue to utilise this after the cessation of the study if I choose to.
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. 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 understand that my identity will be protected and I can, if I wish, have an electronic copy of the finished research document.

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

Participant Name: ……………………………………………………………………………………

Participant Address: ……………………………
………………………………………………
………………………………………………

Participant Signature: …………………………… Date: …………………………………………

Project Researcher: ……………………………………………………………………………………

Researcher Address: ……………………………
………………………………………………
………………………………………………

Researcher Signature: …………………………… Date: …………………………………………

UREC REGISTRATION NUMBER: 2013-1076
This study has been approved by the UNITEC Research Ethics Committee from 20 November 2013 to 13 May 2016. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the UREC Secretary (ph: 09 815-4321 ext 6162). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.
Appendix E.  ACC Official Information Act Request

7 June 2016

W Ferguson
fyi-request-4007-e41df870@requests.fyi.org.nz

Dear W Ferguson

Official Information Act Request

Thank you for your email of 16 May 2016, asking for the following information under the Official Information Act 1982:

1. the total number of claim applications for a musculoskeletal work-related gradual process injury (accepted or declined) per year
2. the total number of accepted claim applications for a musculoskeletal work-related gradual process injury per year
3. the resultant costs per year for musculoskeletal work-related gradual process injury claims

Our Response

In response to your request, we are happy to provide the data outlined in the tables below. Please note the following limitations to the data provided:

- Data is provided for financial years which are 1 July to 30 June.
- Decisions on whether a claim is accepted or declined can and do change over time, for example if more information is received about the claim. The information was extracted on 24 May 2016; the results may change if the table is re-run at a later date.
- Costs provided are exclusive of GST.
- Costs are based on payment date and include costs of all musculoskeletal work-related gradual process (WRGP) claims paid in that year, whether or not they were lodged in that year.
- The data in both tables only include claims lodged with ACC. As Accredited Employer claims are managed separately, and may not be reported to the Corporation, they have not been included.

The following table shows the number of musculoskeletal work related gradual process injury claims lodged (accepted and declined) each year between 1 July 2010 and 30 June 2015.

<table>
<thead>
<tr>
<th>Claim cover decision</th>
<th>2010/11</th>
<th>2011/12</th>
<th>2012/13</th>
<th>2013/14</th>
<th>2014/15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accept</td>
<td>5,891</td>
<td>5,436</td>
<td>4,907</td>
<td>5,962</td>
<td>5,663</td>
</tr>
<tr>
<td>Decline</td>
<td>4,044</td>
<td>4,017</td>
<td>3,852</td>
<td>3,212</td>
<td>3,176</td>
</tr>
<tr>
<td>Total</td>
<td>9,935</td>
<td>9,453</td>
<td>8,759</td>
<td>9,174</td>
<td>8,838</td>
</tr>
</tbody>
</table>
The following table shows the costs paid each payment year for musculoskeletal work related gradual process claims between 1 July 2010 and 30 June 2015.

<table>
<thead>
<tr>
<th>Year</th>
<th>2010/11</th>
<th>2011/12</th>
<th>2012/13</th>
<th>2013/14</th>
<th>2014/15</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ Cost</td>
<td>69,005,115</td>
<td>58,716,057</td>
<td>58,349,087</td>
<td>63,492,410</td>
<td>70,927,067</td>
</tr>
</tbody>
</table>

Comments and queries
If you have any questions about the information provided, I will be happy to work with you to resolve these. I can be contacted via email at GovernmentServices@acc.co.nz.

You also have the right to make a complaint to the Office of the Ombudsman. You can call them on 0800 802 602, 9am to 5pm weekdays, or write to:

The Office of the Ombudsman
PO Box 10 152
WELLINGTON 6143

Yours sincerely

Government Services
Appendix F.  Actigraph GT3X+ Inclinometer Device & Placement

Figure 19.  Actigraph GT3X+ Dimensions

Figure 20.  Actigraph GT3X+ Wear Placement
In this picture you can see the approximate position of most body areas referred to in the questionnaire. Limits are not sharply defined, and certain parts overlap. You should decide for yourself in which area you have had your trouble (if any).

SECTION A

In this picture you can see the different parts of the body referred to in the survey. You will be asked if you have, or have had, any trouble (that is, sore, pain, or discomfort) in these different parts of the body. For example, "head trouble" refers to any pain or discomfort you have had in the shaded area labeled "head."
* 1. During the past week, how troublesome have each of the following body areas been? Please answer every question, even if you have never had trouble in any part listed below.

<table>
<thead>
<tr>
<th>Area</th>
<th>No pain experienced</th>
<th>Not at all troublesome</th>
<th>Slightly troublesome</th>
<th>Moderately troublesome</th>
<th>Very troublesome</th>
<th>Extremely troublesome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headache</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neck pain</td>
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<tr>
<td>Shoulder pain</td>
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<tr>
<td>Elbow pain</td>
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<tr>
<td>Wrist/Hand pain</td>
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<tr>
<td>Chest pain</td>
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<tr>
<td>Abdominal pain</td>
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<tr>
<td>Upper back pain</td>
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<tr>
<td>Lower back pain</td>
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<tr>
<td>Hip/thigh pain</td>
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<tr>
<td>Knee pain</td>
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<tr>
<td>Ankle/foot pain</td>
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<tr>
<td>Other pain</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
2. How many separate episodes of this trouble (ache, pain, discomfort) have you had the last week that you feel is related to your work?

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7 (daily)</th>
<th>8 or More (multiple episodes per day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headache</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neck pain</td>
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<td></td>
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<td></td>
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<tr>
<td>Shoulder pain</td>
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<tr>
<td>Elbow pain</td>
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<tr>
<td>Wrist/Hand pain</td>
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<td>Chest pain</td>
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<td>Abdominal pain</td>
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<td>Upper back pain</td>
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<td>Lower back pain</td>
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<td>Hip/thigh pain</td>
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<td>Knee pain</td>
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<td>Ankle/foot pain</td>
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<td>Other pain</td>
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</table>

* 3. Which body area has been your main area of trouble (ache, pain or discomfort) this week?

- I have had no ache, pain or discomfort this week
- Headache
- Neck pain
- Shoulder pain
- Elbow pain
- Wrist/Hand pain
- Chest pain
- Abdominal pain
- Upper back pain
- Lower back pain
- Hip/thigh pain
- Knee pain
- Ankle/foot pain

Other (please specify)
4. For your main area of trouble (ache, pain, discomfort), please indicate the number that best represents:

<table>
<thead>
<tr>
<th>0 (No pain)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10 (Worst pain imaginable)</th>
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</thead>
<tbody>
<tr>
<td>Your worst pain level this week</td>
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<td>Your best pain level this week</td>
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<td>Your current pain level</td>
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</table>

As you read the list, think of yourself in the past week. When you read a sentence that describes your back in the past week, put a tick against it. Remember, only answer yes to the sentence if you are sure it describes you in the past week.

5. I stay at home most of the time because of my back.
   - Yes, this describes me in the past week
   - No, this does not describe me in the past week

6. I change position frequently to try and get my back comfortable.
   - Yes, this describes me in the past week
   - No, this does not describe me in the past week

7. I walk more slowly than usual because of my back.
   - Yes, this describes me in the past week
   - No, this does not describe me in the past week

8. Because of my back I am not doing any of the jobs that I usually do around the house.
   - Yes, this describes me in the past week
   - No, this does not describe me in the past week

9. Because of my back, I find use a handrail to get upstairs.
   - Yes, this describes me in the past week
   - No, this does not describe me in the past week
* 10. Because of my back, I lie down to rest more often.
   - [ ] Yes, this describes me in the past week
   - [ ] No, this does not describe me in the past week

* 11. Because of my back, I have to hold on to something to get out of an easy chair.
   - [ ] Yes, this describes me in the past week
   - [ ] No, this does not describe me in the past week

* 12. Because of my back, I try to get other people to do things for me.
   - [ ] Yes, this describes me in the past week
   - [ ] No, this does not describe me in the past week

* 13. I get dressed more slowly because of my back.
   - [ ] Yes, this describes me in the past week
   - [ ] No, this does not describe me in the past week

* 14. I only stand for short periods of time because of my back.
   - [ ] Yes, this describes me in the past week
   - [ ] No, this does not describe me in the past week

* 15. Because of my back, I try not to bend or kneel down.
   - [ ] Yes, this describes me in the past week
   - [ ] No, this does not describe me in the past week

* 16. I find it difficult to get out of a chair because of my back.
   - [ ] Yes, this describes me in the past week
   - [ ] No, this does not describe me in the past week

* 17. My back is painful all the time.
   - [ ] Yes, this describes me in the past week
   - [ ] No, this does not describe me in the past week

* 18. I find it difficult to turn over in bed because of my back.
   - [ ] Yes, this describes me in the past week
   - [ ] No, this does not describe me in the past week
* 19. My appetite is not very good because of my back pain.
   - Yes, this describes me in the past week
   - No, this does not describe me in the past week

* 20. I have trouble putting on socks or stockings because of the pain in my back.
   - Yes, this describes me in the past week
   - No, this does not describe me in the past week

* 21. I only walk short distances because of my back.
   - Yes, this describes me in the past week
   - No, this does not describe me in the past week

* 22. I sleep less well because of my back.
   - Yes, this describes me in the past week
   - No, this does not describe me in the past week

* 23. Because of my back pain, I get dressed with help from someone else.
   - Yes, this describes me in the past week
   - No, this does not describe me in the past week

* 24. I sit down most of the day because of my back.
   - Yes, this describes me in the past week
   - No, this does not describe me in the past week

* 25. I avoid heavy jobs around the house because of my back.
   - Yes, this describes me in the past week
   - No, this does not describe me in the past week

* 26. Because of my back pain, I am more irritable or bad tempered with people than usual.
   - Yes, this describes me in the past week
   - No, this does not describe me in the past week

* 27. Because of my back, I go upstairs more slowly than usual.
   - Yes, this describes me in the past week
   - No, this does not describe me in the past week
28. I stay in bed most of the time because of my back.

- Yes, this describes me in the past week
- No, this does not describe me in the past week

29. Please comment below if you would like to add information regarding your experiences in the last week (e.g. illness was affecting your work or pain levels, difficulties with desk use, new or different pain was noted)

Thank you for completing this survey. Your input has been extremely valuable.
Full name of author: Whitney Ferguson


Department of

Degree: Master of Osteopathy Year of presentation 2016

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