Title Page

Feasibility of Using Pedometer-Driven Walking to Promote Physical Activity, and Improve Health-Related Quality of Life Among Meat Processing Workers.

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A thesis submitted for the degree of
Doctor of Philosophy at the
University of Otago, Dunedin, New Zealand

December 2014

Abstract

In New Zealand, meat processing populations face many health problems as a result of the nature of work in meat processing industries. Workplaces are a sedentary setting for many workers, which can increase the risk of chronic disease and public health issue. Current evidence supports the use of pedometers as effective motivational tools to promote physical activity and improve health-related quality of life in the general population. To address these issues, the aim of this study is to examine whether a pedometer-driven walking programme can improve health-related quality of life, and increase ambulatory activity in a population of meat processing workers when compared to a control group receiving educational material alone.

A narrative literature review was conducted to define the current knowledge around the epidemiology of injury(musculoskeletal disorders) in the meat processing industry; the benefits of physical activity with regards to chronic diseases and musculoskeletal diseases**;** as well as the use of pedometers as monitors and motivational tools for increasing physical activity. The findings from the literature review reported a high prevalence of musculoskeletal conditions in the meat processing industry with frequent causes in disability. The benefits of physical activity for management of different chronic conditions are also well documented.

A systematic review of using a pedometer-based walking intervention in patients with musculoskeletal disorders (MSD) was conducted. A comprehensive search identified seven randomised controlled trials (RCTs) which examined the effectiveness of pedometers to increase physical activity levels and improve physical function and pain in patients with MSD in the short term. The key findings include a positive change in level of physical activity (step counts), providing strong evidence (level 1) for the effectiveness of pedometer-based walking interventions in increasing physical activity levels for patients with MSDs.

A randomized controlled trial (RCT) study in meat processing industry was conducted. A convenience sample of meat workers (n=58; mean age 41 years) participated in the RCT study. Participants were randomly allocated into two groups. Intervention participants (n=29) self-monitored physical activity using a pedometer, took part in goal setting, and received a step calendar, a brief intervention, regular text and email messages, and educational material. Control participants (n=29) received educational material only. The primary outcomes of ambulatory activity, health-related quality of life, and functional capacity, were evaluated at baseline, immediately following the 12-week intervention and then at three months post-intervention. Following implementation of the 12-week pedometer-based intervention, the findings show a high level of adherence (91%) to the pedometer intervention programme. There was a significant difference in step-count between the groups after the 12-week intervention (mean group difference (MGD) = 1723; 95% CI, 1188 to 2258, $p<0.005$, effect size (ES) = 1.9). In addition, the total metabolic equivalent (T.MET) for self-reported International Physical Activity Questionnaire (IPAQ-SF) showed a statistically significant between-group difference after the 12-week intervention ($p<0.005$, MGD=484, 95% CI, 362 to 606, ES=1.1). Further, results showed non-significant between-group differences in physical component (PCS) and mental component (MCS) scores (PCS: $p=0.44$; MGD=0.99, 95% CI, -1.6 to 3.6; ES=0.14, and MCS: $p=0.90$, MGD = 0.15; 95% CI, -2.3 to 2.6, ES=0.022) after the 12 week intervention.

Conclusions:

This research provides important information for the design of a fully powered RCT in the future: results demonstrated that a pedometer-driven walking intervention is feasible and effective in increasing step count within the workplace setting (meat processing populations) over the short term. A pedometer-based intervention significantly increased physical activity levels (step count) compared to the control group. The meat worker population were accepting to this style of intervention and were compliant with the prescribed programmes of additional physical activity.

Acknowledgements

This thesis would not have been possible without the help and support of my supervisors Prof. G. David Baxter, Associate Professor Stephan Milosavljevic, Dr Steve Tumilty, and Dr Paul Hendrick. Thank you so much for giving me the opportunity to join your group and work and carry out a PhD under your supervision. I am really grateful for your patience and support throughout the PhD period, and for providing excellent and constructive comments on my thesis draft even during your weekends and holidays. A special thank you to Associate Professor Stephan Milosavljevic who has always provided encouragement for my family throughout this journey.

I wish to acknowledge Professor Suzanne McDonough, University of Ulster, UK, for advice on the intervention and trial design, and Mr Chris Higgs, School of Physiotherapy, University of Otago, for advice on the development of the brief intervention.

I would like to express my thanks to the University of Otago (Postgraduate Scholarship) and Mark Steptoe Memorial Trust for providing funding support to conduct this research. I would like also to thank all past and present PhD students and all staff at the School of Physiotherapy, University of Otago. I am also very grateful to all the people who volunteered to participate in this research and all Silver Fern Farms staff. Finally, I could not have accomplished this thesis without the love and support of my wife, Sahar, and my family. I love you so much.

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Mansi, S., S. Milosavljevic, G. D. Baxter, S. Tumilty and P. Hendrick (2013). "Use of pedometer-driven walking to promote physical activity among meat processing workers: a feasibility trial." Sport Science in the Heart of the Arab Spring2 Conference, Hurghada, Egypt.

Mansi, S., S. Milosavljevic, G. D. Baxter, S. Tumilty and P. Hendrick (2013). **"**A systematic review of studies using pedometers as an intervention for musculoskeletal diseases." (Currently under review with BMC Musculoskeletal Disorders)

1 Chapter One

General Introduction

1.1 Background

The meat processing industry is the second most important sector in the New Zealand (NZ) economy, employing approximately 24,000 workers, and contributing approximately 13% of New Zealand's exports (Tappin, Bentley et al. 2008). Meat processing involves different work stages that include slaughtering, boning, cutting, and packing, which demand different physical workloads and tasks. These often require prolonged periods in task-related non-neutral postures, potentially leading to an increased risk of occupational injuries.

Work-related disorders and occupational injuries reported to afflict workers in the meat processing industry are varied, with musculoskeletal disorders (MSD) being a commonly reported health problem (Kristensen 1985; Campbell 1999; Tappin, Bentley et al. 2008). Relevant risk factors include hazardous working conditions (Campbell 1999; Omokhodion and Adebayo 2013) with repetitive movements, heavy physical workload, and sustained standing (Gangopadhyay and Ray 2000; van Rijn, Huisstede et al. 2009; Arvidsson, Balogh et al. 2012) that have been linked to increased levels of disability, sick leave, and work incapacity (Ilardi 2012). The prevalence of MSD among meat processing workers has been previously published (Tappin, Bentley et al. 2008). For example meat processing in the USA is considered one of the most hazardous industries, with an overall incidence injury rate of 6.9 per 100 fulltime workers in 2009 (Bureau of Labor Statistics 2009), while in Canada, the incidence injury rate was 23.48 per 1,000 (Yassi, Sprout et al. 1996). The most common injuries usually involve the upper extremities (Lipscomb, Epling et al. 2007; McPhee and Lipscomb 2009; Mohammadi 2012), with shoulder, and neck, as well as lower back, having the highest reported incidence (Chiang, Ko et al. 1993; Ohlsson, Hansson et al. 1994; Stuart-Buttle 1994; Quandt, Grzywacz et al. 2006; Sormunen, Oksa et al. 2006; Nag and Nag 2007; Widanarko, Legg et al. 2011; Mohammadi 2012; Schulz, Grzywacz et al. 2012).

These conditions are known to impact on health-related quality of life, increase healthcare costs, and also decrease daily activities (Bergman, Jacobsson et al. 2004). It has also been reported that adults with MSD have an overall poorer health-related quality of life than the general population reporting no pain (Bergman, Jacobsson et al. 2004; Mäntyselkä, Turunen et al. 2004); this effect is likely to be increased among aging employees due to the health problems that accrue over a working life-span. Reduction of these risk factors is the goal of most preventive approaches in the workplace setting to reduce the incidence and impact of MSD at the primary and secondary level. Physical activity interventions are considered to be one of the most inexpensive approaches to increase the fitness and exercise capacity and reduce the burden of musculoskeletal conditions on both individuals and society as well as improve health-related quality of life (HRQL) as a positive outcome for increased physical activity.

1.2 **Theoretical models**

Theoretical constructs derived from the Social Cognitive Theory, and Self-Regulation Theory (Baumeister, Gailliot et al. 2006) have been used to gain insight into how individuals decide to become physically active.

1.2.1 Social cognitive theory

The social cognitive theory (SCT) has been used successfully in health education and health behaviour programs and includes the following three constructs: personal factors (internal thoughts and feelings about a behaviour such as self-efficacy and outcome expectations), behavioural factors (knowledge and skills related to a health behaviour), and environmental factors (perceptions of and the actual physical and social environment) (Bandura 2004). The main hypothesis of the model is that the three factors are constantly influencing each other. This theory explains how people acquire and maintain certain behavioural patterns through observation, modelling, and motivation such as positive reinforcement (Bandura 2004). For instance, when an individual adopts physical activity(behavioural factor), self-efficacy will increase (personal factors), and as self-efficacy increases, the individual will continue to successfully adhere to the physical activity regimen (Bandura 1998, Bandura, 2004 #6973).

1.2.2 Self-regulation theory

Self-regulation theory (SRT) has been established as useful for understanding motivation, adherence to exercise, cognition, and as an effective strategy to increase physical activity as well as health behaviours. The major self-regulation mechanism works through three principles: self-monitoring, goal setting and activation and use of goal setting (Baumeister, Gailliot et al. 2006). Several studies have demonstrated that self-regulation behavioural strategies were effective in changing walking behaviour among adults by setting a specific goal and/or self-monitoring interventions (Conn, Hafdahl et al. 2008; Dombrowski, Sniehotta et al. 2012; Sniehotta, Presseau et al. 2012). In addition, a large number of studies have used pedometer -based interventions to enhance and motivate individuals to increase their physical activity by using SRT strategy within a range of conditions. These include weight reduction (Richardson, Newton et al. 2008; Sugden, Sniehotta et al. 2008; Pal, Cheng et al. 2009), and improving pain in adults with MSD (Talbot, Gaines et al. 2003; Fontaine and Haaz 2007), with an aim to encourage increased habitual physical activity and improve health-related quality of life.

1.3 **Physical activity concept**

Daily physical activity is defined as "*any bodily movement produced by the skeletal muscle that results in energy expenditure"* (Caspersen, Powell et al. 1985). Physical activity can be classified in different ways including intensity, duration, type, frequency and context (Rafferty, Reeves et al. 2002; Haskell, Lee et al. 2007). Intensity refers to how much energy is required by muscle when exercising. For example, moderate-intensity corresponds to around 3 to 5 metabolic equivalents (METs) or 55-69% of Maximal Heart Rate (Haskell, Lee et al. 2007), while vigorous-intensity physical activity corresponds to around 7 to 9 METs (Haskell, Lee et al. 2007). One MET is defined as 1 kcal/kg/hour and is equal to the energy produced per unit surface area of an average person obtained during quiet sitting (Ainsworth, Haskell et al. 2011). Moderate-intensity and vigorous-intensity physical activity are the most common activities engaged in by the adult population (Rafferty, Reeves et al. 2002). However, these four principles are all modifiable, knowing that independently or combined they are necessary for providing valuable insight for future intervention programmes. In general, these principles may apply for both the diseased and the healthy adult; however, the ways in which they are applied differ, and appropriate adjustments in each of these principles are necessary for most populations (Myers 2008). Therefore, walking is deemed to be one of the most effective forms of physical activity as it is usually carried out in several activity types, including occupational, transportation, leisure time, and household, with little risk of injury (Siegel, Brackbill et al. 1995) helping to promote and maintain health status in the general population.

1.4 **Physical activity benefits**

Physical activity plays an important role in the prevention and management of various chronic diseases including sedentary obesity, high blood pressure, and cardiovascular disease (Katzmarzyk and Lear 2012; Li and Siegrist 2012; Rossi, Dikareva et al. 2012), and is associated with a reduction in premature mortality and improvement in quality of life (Warburton, Nicol et al. 2006). In recent years many studies have demonstrated the benefit of increased physical activity in reducing pain and improving quality of life in workplace populations with MSD (Andersen, Christensen et al. 2010; Zebis, Andersen et al. 2011); reducing musculoskeletal impairment in the elderly (Benedetti, Berti et al. 2008) and reducing pain for those with low back pain (LBP) (Jones, Stratton et al. 2007; Kuukkanen, Malkia et al. 2007), neck pain, and shoulder pain (Bernaards, Ariens et al. 2007). Moderate physical activity from walking is considered to be an ideal form of physical activity, helping to promote and maintain health status in the general population (Siegel, Brackbill et al. 1995) and workplace setting (Conn, Hafdahl et al. 2009; Harding, Freak-Poli et al. 2013). It is suitable for all groups, with little risk of injury among low-activity populations (Siegel, Brackbill et al. 1995; Brownson, Housemann et al. 2000 ; National Institute of Clinical Excellence 2006). A summary of evidence for the relationship between physical activity and reduced risk of chronic disease is presented in Table 1.

Table 1: Summary of evidence: The relationship between physical activity and chronic diseases

Conditions	Effect
Cardiovascular disease CVD	Decreased risk from 10-20% [1]
Stroke	Decreased risk from 10-20% [1]
Coronary heart disease	Decreased risk from 20-30% [1,2]
Systolic blood pressure	Decreased from 5-10 mmHg [3]
Diastolic blood pressure	Decreased from 1-6 mmHg [3]
All-cause mortality	Decreased risk by 30% [4]
Type 2 diabetes and metabolic syndrome	Decreased risk from 30-40% [4]
Colon cancer	Decreased risk from 13-14% [5]
Prostate cancer	Decreased risk by 20% [5]
Breast cancer	Decreased risk by 20% [6]
Hip fracture	Decreased risk from 3.6 - 6.4 % [7]
Falls in older people	Decreased risk from 30-50% [8]
Osteoarthritis	Decreased risk from 22-80 % [4]
Psychological well-being	Improved by 30% [4]
Depression	Decreased risk from 20-30% [4]

1.(Li and Siegrist 2012), 2 (Sattelmair, Pertman et al. 2011), 3 (Semlitsch, Jeitler et al. 2013), 4 (Physical Activity Guidelines Advisory Committee 2009), 5 (Anzuini, Battistella et al. 2011), 6 (Moore, Gierach et al. 2010), 7 (Babatunde, Forsyth et al. 2012), 8 (Paterson and Warburton 2010).

1.5 Physical activity recommendation

Despite the well-known benefits of regular physical activity for the prevention and management of different chronic conditions (Warburton, Nicol et al. 2006); more than 31% of adults do not take part in recommended levels of physical activity (World Health Organization 2011b; Lee, Shiroma et al. 2012) which leads to increase the health risks related to insufficient physical activity, and also increase the economic burdens on the health care system. Therefore, the priorities of physical activity guidelines are to increase the levels of activity to achieve health benefits across the life span, which are consistent with several physical activity studies showing that increasing the level and capacity for Physical activity may help lead to a reduction in occupational injury and improve health-related quality of life as well as reduce the costs of treatment (McEachan, Lawton et al. 2008; Pronk 2009; Méndez-Hernández, Dosamantes-Carrasco et al. 2012).

The national and international guidelines have developed the recommendations on physical activity for health and recommended that every adult accumulate at least 150 minutes of moderate intensity physical activity weekly, or 75 minutes per week of vigorous-intensity aerobic physical activity, or a combination of the two intensities to gain significant health benefits (World Health Organisation 2011). To gain substantial health benefits, it is recommended to accumulate bouts of 10 or more minutes each day. The New Zealand Physical Activity Guidelines advise that adults should participate in at least 30 minutes of moderate activity on most, if not on all days of the week (Ministry of Health 2001). Data from Sport and Physical Activity Surveys NZ 2008 (Sport and Recreation New Zealand 2008) show that 48.2 % of NZ adults are physically active on five or more days per week, while the New Zealand Health Survey 2012 (Ministry of Health 2012), found greater levels (54%) of adults that met the current recommendations of physical activity daily.

1.6 **Physical activity intervention programmes**

In developed countries, modern conveniences and technology have contributed to increasing physical inactivity among adults. For example, World Health Organization (WHO) reported in 2008, 31% of adults exhibit a sedentary lifestyle, and have a 20-30% increased risk of mortality compared to active people (World Health Organization 2011; Lee, Shiroma et al. 2012). Therefore, increasing the level of physical activity to help them become more active, and hence reduce the burden of chronic diseases and improve health- related quality of life (HRQL) is considered important. In recent years there has been an increasing interest in research regarding physical activity. Physical activity interventions are often recommended for increasing physical activity and to minimize risk, as well as improve quality of life for various chronic diseases, including sedentary obesity, high blood pressure, and cardiovascular disease (Warburton, Nicol et al. 2006; Katzmarzyk and Lear 2012; Li and Siegrist 2012; Rossi, Dikareva et al. 2012). A number of systematic reviews in this area support the effectiveness of walking based interventions for improving overall health (Albright and Thompson 2006; Ogilvie, Foster et al. 2007; Hendrick, Wake et al. 2010; Lee, Watson et al. 2010; Robertson, Robertson et al. 2012; Polese, Ada et al. 2013) among different population with or without conditions. In addition, evidence from numerous systematic reviews of physical activity interventions (Proper, Koning et al. 2003; Bravata, Smith-Spangler et al. 2007; Richardson, Newton et al. 2008; Kang, Marshall et al. 2009; Funk and Laurette Taylor 2013; Qiu, Cai et al. 2014) have concluded that pedometer-based walking interventions are a more effective strategy in increasing physical activity than walking alone in adult populations.

1.7 Pedometers

Pedometers are devices that are able to assess walking-related physical activity by recording the number of walking steps over time (Lubans, Morgan et al. 2009). There are different commercial brands of pedometers available on the market for the objective assessment of physical activity in population groups. The most commonly used devices in research to assess and promote physical activity are The Yamax Digi-walker series pedometer (Crouter, Schneider et al. 2003). The Yamax Digi-walker was found to be the most accurate pedometer in counting steps; recording between 1-3% error of actually step count (Le Masurier, Lee et al. 2004; Feito, Bassett et al. 2012). Pedometers are useful tools that can supply valuable information on the number of steps and distance travelled allowing individuals to track their ambulatory activity (Tudor-Locke, Williams et al. 2004; Tudor-Locke and Lutes 2009). In clinical studies pedometers have been widely used in the assessment and management of different diseases including sedentary overweight (Sugden, Sniehotta et al. 2008; Pal, Cheng et al. 2009), diabetes (Furber, Monger et al. 2008) , COPD patients (Hospes, Bossenbroek et al. 2009), with an aim to encourage increased habitual physical activity, and improve health-related quality of life.

1.8 Use of pedometers in physical activity programmes

Pedometer intervention programmes can help participants understand the importance of physical activity and provide the means to change their behaviour. Interventions are often based on physical activity behaviour theories and models, which is consistent with physical activity guidelines and public health recommendations for physical activity with the goal of increasing physical activity. This generally includes: goal setting, feedback and self-monitoring, educational materials, website contact, counselling sessions, and follow-up contact (Tudor-Locke and Lutes 2009). Recently Qiu et al (2014) completed a systematic review of pedometer-based interventions that reported significantly increased physical activity by 1,822 steps per day; 95% confidence interval (CI): 751 to 2,894 steps per day) in patients with type 2 diabetes. Consistent with evidence from numerous systematic reviews of pedometer-based intervention studies on a variety of populations support the beneficial effects of this method in increasing habitual physical activity, and improve a wide range of health outcomes in the short- term (Bravata, Smith-Spangler et al. 2007; Richardson, Newton et al. 2008; Kang, Marshall et al. 2009; Lubans, Morgan et al. 2009).

Pedometer based-walking interventions are also becoming widely used as motivational tools to increase the level of physical activity in the workplace settings. While workplaces are a sedentary setting for many workers they have also been internationally recognized as an ideal setting for health promotion and physical activity strategies, as most workers spend about a third of their waking hours at the workplace (Dishman, Oldenburg et al. 1998; Christie, O'Halloran et al. 2010; Malik, Blake et al. 2013). A number of studies show that participating in pedometer-based walking programmes in the worksite has positive health benefits for the employees (Chan, Ryan et al. 2004; Maruyama, Kimura et al. 2010; Freak-Poli, Cumpston et al. 2013; Harding, Freak-Poli et al. 2013) and also reduces the costs of treatment and claims for compensation (Odeen, Magnussen et al. 2013) and increases production capacity (Kahn, Ramsey et al. 2002). Systematic reviews of workplace physical activity interventions have concluded that workplace-based walking interventions can be efficacious in promoting physical activity when using pedometers (Proper, Koning et al. 2003; Dugdill, Brettle et al. 2008; To, Chen et al. 2013) and may provide a larger increase in activity.

1.9 Statement of the problem

Physical inactivity is a significant public health issue in NZ. It contributed to non-communicable diseases and health problems which cost NZ approximately $1.3 billion for the 2010 year (Lee, Shiroma et al. 2012; Market Economics Limited 2013). The phenomenon of inactivity is prevalent: approximately 46% of NZ adults do not meet the current recommendations of daily physical activity (Ministry of Health 2012). Worldwide, the highest rates of inactivity are among workplace adults (Grosch, Alterman et al. 1998; Marshall 2004; Puig-Ribera, McKenna et al. 2008), with 79% of US employees worked at sedentary- and light-intensity jobs; represented approximately11 hour per day in sedentary behaviors (Tudor-Locke, Leonardi et al. 2011). For NZ adult workers, previous research (Schofield, Badlands et al. 2005) has reported a high prevalence of inactivity (57%) measured by pedometer across six different workplace settings (Schofield, Badlands et al. 2005). The population of meat-workers in NZ is ageing and has health-related issues consistent with an ageing population, a sedentary lifestyle, and chronic disease that include obesity, hypertension, diabetes, and other cardiopulmonary problems (Ivanov and Ivanov 2000; McLean, Cheng et al. 2004). Although these factors can impact adversely on work productivity and sick leave (Ilardi 2012), they are also known to positively respond to increased physical activity (Li and Siegrist 2012; Rossi, Dikareva et al. 2012). A healthier more active work force will likely be associated with reduced sick leave, reduced injury rates, and increased productivity (Puig-Ribera, McKenna et al. 2008).

1.10 **Significance of study**

There have been numerous physical activity intervention studies implemented in the worksite setting (Chan, Ryan et al. 2004; Thomas and Williams 2006; Puig-Ribera, McKenna et al. 2008; Freak-Poli, Wolfe et al. 2011) to improve health-related outcomes and increase the physical activity levels of employees. Employers may benefit directly through reduced absenteeism and sick leave, as well as increased workplace productivity (McEachan, Lawton et al. 2008; Pronk 2009; Méndez-Hernández, Dosamantes-Carrasco et al. 2012). For example, a New Zealand study estimated that a 5% increase in physical activity from the general popoulation could result in savings of $25 million per annum in direct health costs. Significant savings of $160 million per annum have been also estimated if all New Zealanders were physically active (Bauman 1997). Therefore, employing a simple, cheap, performance driven physical intervention, and one that is socially interactive, may be a significant step towards improving the health and lifestyle of these workers. To our knowledge, no study has employed pedometer-driven walking as a motivational strategy and intervention together with goal setting in order to increase daily physical activity among meat processing workers.

1.11 **Purpose of the study**

The primary aims of this thesis are to evaluate the feasibility and effectiveness of using a pedometer-based intervention programme, incorporating a brief intervention along with educational material, to increase physical activity and improve health-related quality of life in a population of meat processing workers, when compared to a control group receiving educational material alone. Secondary effects on blood pressure, body mass index, body fat percentage, and waist circumference will also measured. I hypothesize that the pedometer-driven walking intervention will be a feasible and effective tool to increase participants' daily physical activity levels and improve health outcomes compared to a control group.

1.11.1 The specific objectives were:

(a) To review the published literature about musculoskeletal disorders and occupational injury (Chapter Two).
(b) To review the published literature regarding the benefit of measuring physical activity (Chapter Three).
(c) To review the published literature regarding pedometer-based intervention within a workplace setting (Chapter Four).
(d) To investigate the evidence for effectiveness of pedometer-driven walking programmes to promote physical activity among patients with musculoskeletal disorders (Chapter Five).
(E) To evaluate the feasibility and acceptability of using a pedometer-based intervention programme to promote physical activity among meat processing workers (Chapter Six).

1.12 **Thesis structure**

This thesis contains eight chapters. Following this introduction, chapter 2 provides an overview of MSD and occupational injury and outlines MSD prevalence in the meat processing industry. This acts to inform the depth of this occupational problem, and to better understand the nature of work which results in increased risk of work-related MSD. Chapter three focuses on physical activity recommendations, and provides more detail on the benefits of physical activity. Evidence for a relationship between increased physical activity and decreased risk of chronic conditions is reported (Physical Activity Guidelines Advisory Committee 2009). Chapter three also explores the validity and reliability of the YAMAX Digiwalker pedometer (DW 200), including both free living and laboratory settings with a wide range of populations. The DW 200 pedometer accuracy is consistent across different conditions (laboratory, and free-living) under varying speeds.

An overview of 23 studies using a pedometer based intervention in the workplace is also presented in chapter four, highlighting a number of strengths and weaknesses in the research design and methods of data collection and analysis. The majority of these studies support the utility of pedometers in increasing physical activity and improving other health-related outcomes. The objective of chapter five was to use a systematic review design in order to investigate the strength of evidence for pedometer-driven walking interventions for patients with MSD. This review provides strong evidence for the effectiveness of pedometer-based intervention in increasing physical activity among patients with MDS in the short-term.

Chapter six describes the research design and research methodology, which includes a description of aims, hypothesis, description and selection criteria of participants, randomization, measurement process, intervention protocol, and data collection protocol and statistical analyses. The aims of this chapter were to evaluate the feasibility and effectiveness of using a pedometer-based intervention programme to promote physical activity among meat processing workers at 12 and 24 week follow-up points. The results of this study are presented in chapter seven. Statistical analysis was performed using a repeated measure, mixed model, ANOVA to compare measurements between the control group and the intervention group for the different periods that data were collected. There was a significant difference in step-count between the groups at 12 weeks (mean group difference (MGD) = 1723; 95% CI, 1188 to 2258, $p<0.005$, effect size (ES) = 1.9). General discussion of the findings outlined in chapters two to seven are drawn together in chapter eight. This research has demonstrated that a pedometer-driven walking intervention is feasible and effective for increasing step count within the workplace setting (meat processing populations) over the short term.

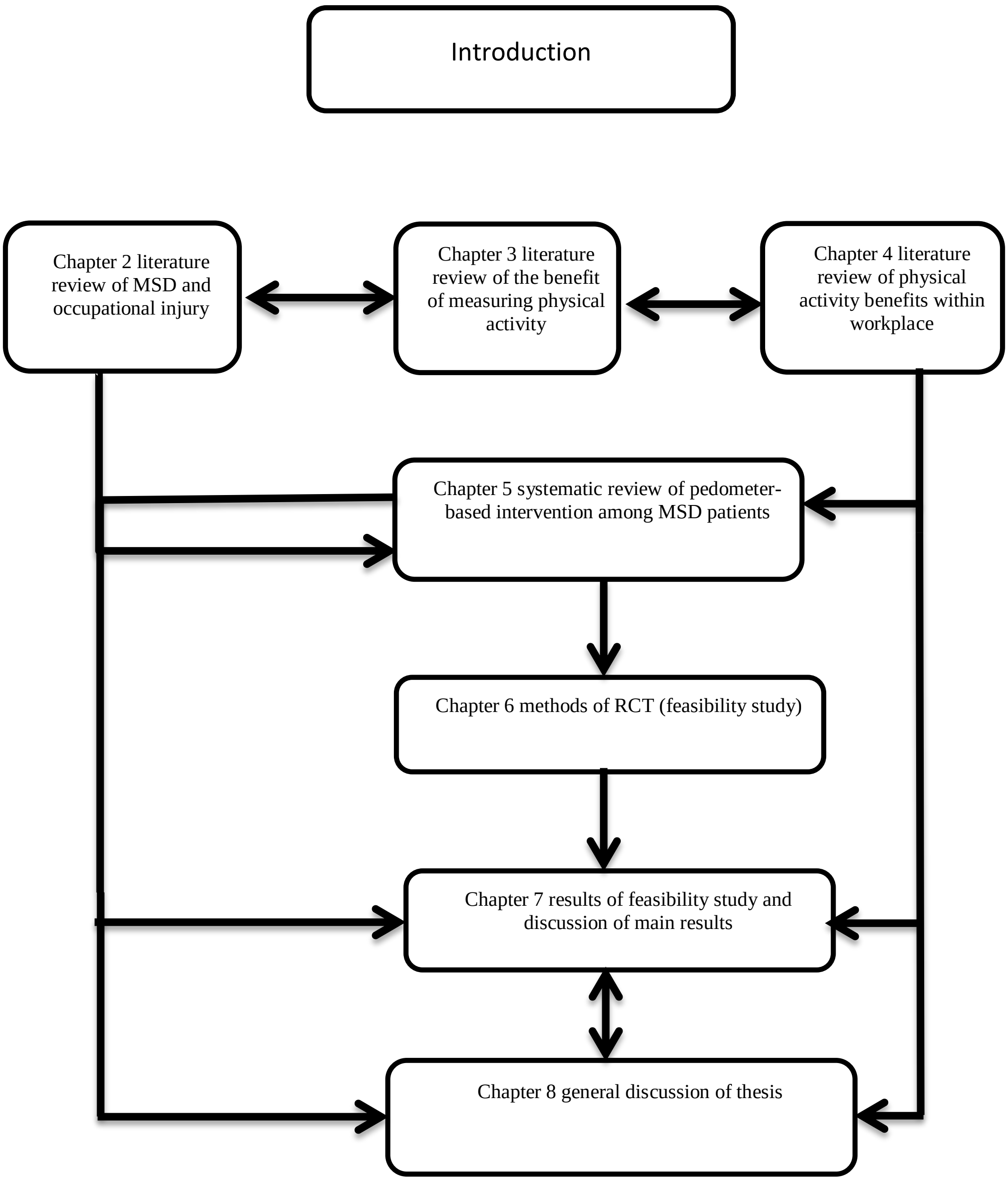

Figure 1: Layout illustration of thesis design

2 Chapter Two

Musculoskeletal disorders and occupational injury: narrative review

2.1 Overview

Occupational diseases are a prevalent and significant health problem among workers (Meksawi, Tangtrakulwanich et al. 2012), globally linked to the premature deaths of approximately 2.34 million people annually and 6300 people daily (The International Commission on Occupational Health 2013). The morbidity of musculoskeletal disorders is a substantial contributor to occupational health disease prevalence by both numbers and by cost. This chapter is a literature review of the incidence and prevalence of work-related musculoskeletal disorders (WMSD) in the occupational setting. The aim of this review is to describe the international prevalence of MSD in general, with a focus on prevalence in a meat processing setting, based on data derived from various resources. In addition, risk factors for WMSD affecting different body parts are outlined.

2.2 Musculoskeletal disorders (MSDs)

The burden of musculoskeletal disorders (MSDs) is increasing for both individuals and public health systems (Punnett and Wegman 2004). This is considered a global health problem with social and economic impacts on health and quality of life as well as long term disability in individuals and communities (Buckle and Jason Devereux 2002; Osborne, Nikpour et al. 2007; Collins, Janse van Rensburg et al. 2011). Musculoskeletal conditions involve nerves, bones, tendons, muscles, and other related soft tissues of the body. In 2010 the Global Burden of disease (GBD) was reported as nearly 777 million years lived with disability (YLDs) from a total of 289 diseases and injuries; the most common causes of YLDs were mental and behavioural disorders, and musculoskeletal disorders related to back injury (Vos, Flaxman et al. 2013).

2.3 Definitions of MSD

MSDs are conditions and injuries that affect body movements in all age groups and frequently cause disability; the term is known to cover a large group of conditions. These are caused by a variety of factors and frequently occur from overuse or repetitive motion involving either muscular or neural tissues (Colombini, Occhipinti et al. 2003).

While there are many definitions of injuries and disorders affecting the musculoskeletal system in the literature (Colombini, Menoni et al. 2005; Boocock, Collier et al. 2009) there is a lack of consensus on the description and application of the term 'workplace overuse injuries' (Melhorn 1998). There appears to be a lack of consensus on the use of standardized criteria, and on the use of a universal classification system (Colombini, Menoni et al. 2005; Boocock, Collier et al. 2009). Different countries use a variety of MSD terms. For example, in New Zealand (NZ), the Accident Compensation Corporation(ACC) describes 18 MSD conditions covering localised inflammations, compression syndromes, and pain syndromes (Boocock, Collier et al. 2009), while the Italian national working group describes MSD as impairments to peripheral musculature, tendon, nerves and the vascular system (Colombini, Occhipinti et al. 2003). Others describe MSD as inflammatory and degenerative diseases and disorders affecting bones and joints (Buckle and Jason Devereux 2002; Punnett and Wegman 2004). Osborne and colleagues define it as the combination of clinical disorders embedded in the clinical fields of orthopedics and rheumatology (Osborne, Nikpour et al. 2007).

There are a number of terms used to group disorders, each of which is dependent on a different classification system (Van Eerd, Beaton et al. 2003; Huisstede, Miedema et al. 2007). For example, repetitive strain injury (RSI) is commonly used in many countries, and includes disorders affecting the back, lower, and upper limbs, and those which occur in muscles, nerves and tendons as a result of work-related repetitive movements, workplace environment, and psychosocial workplace factors (Yassi 2000; van Tulder, Malmivaara et al. 2007). Repetitive strain injury classification encompasses a number of different disorders such as carpal tunnel syndrome, epicondylitis, cubital tunnel syndrome, tendonitis of the wrist or hand, or a variety of symptoms such as numbness, pain, and a wasting and weakening of muscle (Yassi 2000; O'Neil, Forsythe et al. 2001; Van Eerd, Beaton et al. 2003; van Tulder, Malmivaara et al. 2007).

Work-related musculoskeletal disorders (WMSD) is similarly a term used to describe a large group of painful disorders of muscles, tendons, and nerves, affecting the hands, wrists, elbows, neck, and shoulders, and linked to workplace activity (Punnett and Wegman 2004; Boocock, Collier et al. 2009; Collins, Janse van Rensburg et al. 2011). The term cumulative trauma disorders (CTD) has also been widely used in North

America to describe work-related disorders that affect bones, muscles, nerves, and other anatomical features, and resulting from trauma to the body from repetitive overuse or external forces (Melhorn 1998; Zakaria, Robertson et al. 2002; Sobrino Serrano 2003; Sobrino Serrano 2003).

There is much debate comparing epidemiologic principles, and scientific literature regarding terminology and case definitions. Despite variations in terminology and definition, it is recognised that MSD is a widespread global disorder, affecting the back, lower limb, upper limb and neck, with substantial costs and long term disability (Kemmlert 1995). While management of MSD is multidisciplinary and multifaceted, increasing (functional) physical activity levels is considered to be one of the most inexpensive approaches to reduce MSD pain and its burden on the health care system. There is evidence that physical activity interventions provide benefits in primary and/or secondary prevention of low back pain, osteoarthritis, and osteoporosis (Vuori 2001; Roddy, Zhang et al. 2005; Hendrick, Wake et al. 2010), and that workplace physical activity interventions provide similar benefits on MSD (Proper, Koning et al. 2003).

2.4 Musculoskeletal disorder prevalence - globally and in NZ

Definitive information and data on MSD prevalence around the world is still limited, as the majority of countries still do not collect adequate data and relevant statistics for MSD. Table 2 shows the international prevalence of MSD in general populations. MSDs are collectively the most commonly reported workplace illnesses globally. For example, the prevalence of MSDs in the USA was 39 cases per 10,000 workers in 2011. Musculoskeletal disorders accounted for approximately 33% of all workplace injuries and illnesses requiring time away from work. MSDs were predominantly associated with repetitive tasks, awkward postures, and heavy physical work, creating symptoms in the neck, low back, and upper extremities (Bureau of Labor Statistics 2013). On the other hand, there was a decline in the prevalence rate over the 10 years between 2000 and 2010 : for example MSDs accounted for 39 cases per 10,000 workers in 2001/2002, 35 per 10,000 workers in 2007, and 34 per 10,000 workers in 2010, representing approximately 8% decline (Bureau of Labor Statistics 2008; Bureau of Labor Statistics 2011).

Table 2: **Prevalence rate of work-related musculoskeletal disorders**

Country	Year	Source	Averaged rate
USA	2012	Bureau of Labor Statistics	38 per 10,000 workers
USA	2011	Bureau of Labor Statistics	39 per 10,000 workers
USA	2010	Bureau of Labor Statistics	34 per 10,000 workers
USA	2006	Bureau of Labor Statistics	39 per 10,000 workers
GB	2011	The Labour Force Survey	≈145 per 10,000 workers
GB	2010	The Labour Force Survey	≈ 168 per 10,000 workers
EU27	2007	Labour Force Survey 2007	59 % over 12 months
Germany	2007	Labour Force Survey 2007	75% over 12 months
Bulgaria	2007	Labour Force Survey 2007	37% over 12 months
NZ	2010	ACC	109 per 1,000 workers
Australia	2005	National health survey	31% of the population

USA: The United States of America, GB: Great Britain, EU 27: European Union of 27 member states,, and NZ: New Zealand

In 2011/12 UK data reported 439,000 MSDs from a total of 1,073,000 work-related illnesses, with 141,000 new cases and 176,000 individual back disorders. Males, postal work, construction work, and agriculture represented the highest sources of injury. Musculoskeletal disorders were the most common illness type, made up about 40% of all cases of work-related diseases, and accounted for 7.5 million working days (17 days per case) lost. However, the results showed around 80% of new work-related conditions were from MSD and psychological conditions, and the number of MSD over the last years has a downward trend (Health & Safety Executive 2013). Further UK data (Jordan, Kadam et al. 2010) showed a prevalence of 5,908 MSDs per 10,000 workers, with back and knee pain the most common injuries. The Labour Force Survey (LFS) and Consultations in Primary Care Archive (CiPCA) were the main resource for assessing the total of MSD in Great Britain.

Between 2001 and 2007, MSDs were also one of the most common work-related health disorders in mainland Europe (EU), accounting for approximately 38% of the total occupational diseases in 2005 (The International Commission on Occupational Health 2013). In 2007, the Labour Force Survey reported that MSDs accounted for approximately 58% of all diseases, affecting more than 40 million workers, and causing 49.9 % of all absences from work lasting three days or more in the past 12 months in the EU27 (The International Commission on Occupational Health 2013). MSDs represented the lowest proportion of work-related disorders in Bulgaria (37%) and the highest in Germany (75%), with approximately 112 million lost working days and 25,000 persons taking early retirement in 2008.

In Australia MSDs are considered responsible for some form of disability in one in three people, and to represent a major burden on health care systems (Australian Bureau of Statistics 2006). In 2011-2012, the Australian Health Survey (AHS) reported that MSDs (of which osteoporosis and arthritis are the most common health disorders) affected around 14.8% of the population (3.3 million people) and are one of the major causes of chronic pain and disability in Australia (Australian Bureau of Statistics 2013). In the Republic of Korea, the number of claims for MSDs has increased rapidly over the years, from 1,634 cases in 2001 to 5,502 in 2010 (Ministry of Employment and Labour 2011) with a total economic cost of $6.89 billion (Oh, Yoon et al. 2011).

In New Zealand, MSDs affect one in four adults, and account for approximately 25% of the total annual health care budget (Bossley CJ 2009). MSD sprain and strain were the most frequent claims accepted by the ACC, accounting for 36% of the total compensation cost with an incidence rate of 109 work-related injury claims per 1,000 full-time workers in 2010 (New Zealand Accident Compensation Corporation 2011). On the other hand, there were 187,900 work-related injury claims in 2011, resulting in a rate decrease to 97 cases per 1,000 full-time equivalents compared to 2010, representing approximately one third of New Zealanders experiencing injuries every year (New Zealand Accident Compensation Corporation 2012).

Summary:

The prevalence of MSDs on the adult population has been documented.
However, the lack of standardization and validation around the terminology and classification of MSDs is one of the reasons for the different ways to identify the prevalence of MSDs around the world. For example, in the UK the prevalence estimates use self-reported data from national surveys to calculate the likely numbers of people with a particular disease in the practice. New Zealand’s Accident Compensation Corporation (ACC) provides the main source of MSD related statistics in this country,

while in the USA the Bureau of Labor Statistics provider's database records the incidence and treatment for all the claims in the USA.

2.5 Musculoskeletal disorders in the workplace

Work-related musculoskeletal disorders are a health problems of muscles, tendons, nerves, and other related soft tissues of the body. Carpal tunnel syndrome, epicondylitis, tendonitis, thoracic outlet syndrome, cubital tunnel syndrome, and tension neck syndrome are examples (Yassi 2000; O'Neil, Forsythe et al. 2001; Van Eerd, Beaton et al. 2003; van Tulder, Malmivaara et al. 2007).The prevalence of MSD has been investigated in a number of different workplace environments internationally. The problem of MSD in the industry factories were highlighted in several Asian countries over the period 2009-2012. The most common MSD cases recognized as occupational injuries are the shoulder, neck, and upper and lower back complaints.
In China Yu et al (2012) conducted a cross-sectional survey of 60 factories and 3476 workers, and reported an MSD annual prevalence of 50.4%, with 8.3% of workers reporting an acute traumatic injury in the previous 12 months. Longer working hours, previous injury, and high mental stress were associated high risk factors for MSD. Cho and colleagues collected data from 203 computer workers at three companies and one university by two questionnaires in Taiwan, from May to July 2009. Results identified the prevalence of musculoskeletal symptoms (MSS) in three different body regions: the shoulder (73%), neck (71%), and upper back (60%), with the same body regions reported as those with the highest workload: 77.3, 75.6, and 63.9% respectively. Whereas high workload was associated with high MSS, high psychological distress also contributes to increased shoulder, upper and lower back complaints (Cho, Hwang et al. 2012). In another study combining face-to-face interviews, EMG, and a questionnaire for 180 workers in two companies in Taiwan, the prevalence of MSD was 90% across all body regions, with the hand/wrist, shoulder, low back, and elbow being the most commonly affected body parts (41.7, 41.1, 37.8, and 33.3% respectively). High levels of psychosocial stress were also associated with discomfort in several body parts with one in four cleaners (25.6%) reporting an absence from work due to MSD (Chang, Wu et al. 2012).

Among rubber tappers workers in Southern Thailand, low back was the body region identified with the highest incidence of MSD problems (estimated at 53%), followed by the legs, upper arms, neck, wrists, and lower arms. Repetitive twisting, bending, and extension of the trunk were considered as the factors that contributed most to the high risk of low back pain (Meksawi, Tangtrakulwanich et al. 2012). A Brazilian dockworkers' study, collected data from 954 medical files for the years 2000-2009, and reported 15.8% of the workforce suffered from MSDs; of these low back pain affected 38.8%, followed by tendinitis 19.7%, and neck pain 12.5% (de Almeida, Cezar-Vaz et al. 2012).

In India a cross-sectional descriptive study of 246 cashew factory workers identified incidence rates for MSDs in the knee, back, and shoulder of 32.4, 30.9, and 11.8% respectively. Overall prevalence of pain was 28.5%, and was most frequently reported by workers having more than 5 years' experience (Girish, Ramachandra et al. 2012). In Iran around 61% of 1439 steel workers had reported at least one MSD over a 12 month period, with 46.3% in the week prior to the survey. The lumbar spine, knees, and neck were the most frequent complaint of MSD annually (64.1, 47.8, and 44.9% respectively). Long job hours and higher body mass index (BMI) were also associated with these MSDs (Aghilinejad, Choobineh et al. 2012).

Musculoskeletal disorders are one of the most common causes of severe long term pain and disability in NZ and lead to significant healthcare and work absence as well as a major economic cost through lost productivity.The prevalence of MSD in a sample of 3003 workers in NZ was assessed by use of the Nordic Musculoskeletal Questionnaire (NMQ). This study identified an overall prevalence rate of 92%, with low back (54%), neck (43%), and shoulder (42%) being the most frequent sites of complaints over the previous 12 months. Heavy physical workloads were associated with high levels of MSDs in most body regions, with females reporting significantly higher prevalence rates for most body regions compared to males (Widanarko, Legg et al. 2011).

A recent systematic review of 24 studies that covered farming literature until February 2009, found that low back pain was the most frequently reported MSD internationally, followed by the upper and lower extremities. The overall prevalence of MSD was 90.6% and 76.9% for life time and one year respectively (Osborne, Blake et al. 2012).

In this review the majority of these studies had moderate methodological quality with quality scores of >6/10 points; common methodological shortcomings were inadequate sample size, and lack of reporting of confidence interval findings. However, this review is important because farmers are likely to have similar occupational tasks to workers in the meat processing industry including: awkward postures, heavy physical work, and lifting. This is consistent with reports that farmers have higher rates of osteoarthritis, and low back pain than other occupational groups (Walker-Bone and Palmer 2002; Osborne, Blake et al. 2012).

A systematic review of studies of musculoskeletal disorders in dental professionals found the prevalence rate of MSD ranged between 64% and 93%; the back (36.3–60.1%), neck (19.8–85%), and wrists/hands (60–69.5%) were the regions most commonly affected (Hayes, Cockrell et al. 2009). Another systematic review on MSD studies in dentists reported prevalence over the past year by region: shoulders (61.7%), lower back (59.3%), upper back (55.7%), wrists/hands (53.4%), and neck (53.3%) (Lai, Yin et al. 2013).

These data highlight the high frequency of musculoskeletal problems in the workplace setting. Across these studies, the estimates of prevalence rate ranged between 15.8% and 90%, which might be due to variation in outcome assessments such as questionnaires and medical examinations. Determining the prevalence rate of MSD using self-report questionnaires could result in overestimation of the true prevalence rate, compared to other approaches such as medical examination and EMG: assessing MSD prevalence rate in the same group, a prevalence rate of 13% was determined by questionnaire and 3% determined by physical examination (Brisson, Montreuil et al. 1999). Most studies reported prevalence rate over 12 months, while lifetime prevalence is generally considered more accurate (Osborne, Blake et al. 2012). However, some studies did not provide details regarding the validity and reliability of the measurement tools or measure the intensity of pain before conducting their studies (Meksawi, Tangtrakulwanich et al. 2012). Moreover,different classification and diagnostic criteria to describe and define MSD disorders might also have contributed to differences in prevalence rates (Melhorn 1998). Reduction of these rates is the goal of Health and Safety organizations in the workplace setting. The workplace Health and Safety organizations are responsible for work being free of all recognized hazards through better compliance with legal requirements. Therefore, the aim of a Health and Safety organization is the early detection of a health hazard and to trigger action for prevention.

2.6 **Musculoskeletal disorders in meat processing**

MSDs are internationally recognized as a highly prevalent disorder in the meat processing industry, affecting a large number of workers, employers, and compensation organizations as well as various healthcare systems (Wahl, Gunkel et al. 2000; Silverstein, Viikari-Juntura et al. 2002; van Rijn, Huisstede et al. 2009). Work tasks performed in the meat processing industry are considered static and repetitive, with rapid movements of the upper and lower limbs involving knives, slippery floors, live animals, cold exposure, and dangerous machines (Campbell 1999; Culp, Brooks et al. 2008). The meat processing tasks are illustrated in Figure 2

Figure 2: Meat processing operations

Note: Image obtained from http://supportwalter.org/SW/index.php/2011/01/06/slaughterhouse-blues-why-i-am-vegan-part-ii/

Internationally MSDs in the meat processing industry have one of the highest incidence rates for any industry sector, based on the estimated annual incidence of occupational injury by compensating organizations (Silverstein, Viikari-Juntura et al. 2002). In

Canada, meat and poultry processing have been regarded as the highest risk industries with claimed incidence rate of 23.5 per 1,000 full time workers (Yassi, Sprout et al. 1996). In Australia, the incidence rate of injury claims for meat processing was four times higher than for the manufacturing industry, with manual handling claims costing almost 50% more than other injuries (Caple 2003).

Meatpackers in the USA have the highest incident rate of injuries (three times that of other manufacturing industries) that result in death, or permanent or temporary disability (Genaidy, Delgado et al. 1995). More recent data for 2012 indicate the occupational injuries or illness rate was 38 per 10,000 full time workers (Bureau of Labor Statistics 2012), while the incident rate for workers engaged in meatpacking was two times higher than the US national average, with days off work, and job transfer three times higher than the national average (Bureau of Labor Statistics 2012) . In Brazil 20% of meat workers were predicted to suffer from at least one MSD throughout their working life (Buzanello and Moro 2012), similar to Midwestern USA data which identified injuries in 22.8% of full time meat workers per year, with a higher prevalence of injury among women (22.5%) compared to men (17.5%) (Culp, Brooks et al. 2008). In New Zealand the MSD incidence rate for meat processing was estimated to be 59 per 1000 full-time equivalent workers (FTE), compared to 20 per 1000 FTE for forestry and logging, and 16 per 1000 FTE for construction, with high risk for MSDs in the neck and upper extremity due to repetitive tasks, awkward postures, and heavy physical work (Tappin, Bentley et al. 2008). Therefore, MSDs are the primary occupational problem in meat processing in NZ. Besides the direct effect on employee health, this is also a major public health concern due to the costs of health care and compensation claims.

2.6.1 Body parts affected

It is clear that meat processing workers have a high prevalence of MSDs including sprain/strain, dislocation, contusion, laceration, and amputation, with the most common injuries located in the upper extremities (Lipscomb, Epling et al. 2007; McPhee and Lipscomb 2009; Lander, Sorock et al. 2012; Mohammadi 2012). Low back, shoulder, and neck pains also constitute a high proportion of the total injuries (See Table 3) (Chiang, Ko et al. 1993; Ohlsson, Hansson et al. 1994; Stuart-Buttle 1994; Quandt, Grzywacz et al. 2006; Sormunen, Oksa et al. 2006; Nag and Nag 2007; Widanarko, Legg et al. 2011; Mohammadi 2012; Schulz, Grzywacz et al. 2012).

Table 3: **Body part prevalence reported by workers in the meat processing industry**

Study	LBP %	Neck or Shoulder %	Hands/ arms %
(Viikari 1983)	41.7	49.1	59.8
(Tirloni, et al. 2012)	36.4	46-62	25-31
(Ohlsson, et al. 1994)	-	35	10
(Schulz, et al. 2012)	36.8	17-31	30-40
(Quandt, et al. 2006)	36	36	46
(Reis, et al. 2012)	26	29-45	20-23
(Aasmoe, et al. 2008)	49	74	73
(Nag, et al. 2012)	35-54	17-27	17
(Chiang, et al. 1993)	-	30	15

A physical examination of the neck and upper extremities and interviews were performed in 117 slaughterhouse workers. The prevalence of neck and shoulder symptoms was 49.1 %, back pain 41.7% and hands/ arms 59.8% during the past 12 months (Viikari Juntura 1983). Discomfort defined using a human body diagram as a measuring instrument in 290 poultry slaughterhouse workers identified discomfort of shoulders (62.6%), neck (46.2%), spine (36.4%), forearms (31.3%), arms (29.2%), wrists (25.6%) and hands (25.6%) (Tirloni, Dos Reis et al. 2012). A similar survey that used the same instrument reported that 65% of poultry workers had MSD discomfort, with the back having the highest mean maximum intensity followed by the arm (Stuart-Buttle 1994). These results are also supported by a recent review which identified the prevalence of MSD among farmers, and reported that low back pain was the most frequently reported MSD followed by the upper extremity and lower extremity (Osborne, Blake et al. 2012).

Musculoskeletal problems were the most commonly reported work-related injuries in poultry workers in Western North Carolina with arm, wrist, neck and back symptoms reported by 46% of workers (Quandt, Grzywacz et al. 2006). A more recent study was conducted on 403 poultry processing workers and a comparison group of 339 manual workers not employed in poultry processing, and looked at reported problems in the past 12 months that lasted more than one day. Poultry workers reported a greater prevalence of symptoms than other workers. The most frequent symptoms were wrist/hand (40.4%), low back (36.8%), shoulders (30.8%) and neck (17.4%) (Schulz, Grzywacz et al. 2012). These results were similar to those reported by Mohammadi et al. (2012) in workers in the same setting. In addition, Lipscomb et al. (2007) compared women employed in poultry processing with women not working in the poultry industry to evaluate MSD prevalence, and identified a prevalence rate for upper extremity and neck pain 2.4 times higher in female poultry processors.

Carpal tunnel syndrome and lateral epicondylitis are also common and highly prevalent complaints afflicting workers with hand-intensive tasks in the meat and fish processing industries (Chiang, Chen et al. 1990; Viikari-Juntura, Kurppa et al. 1991; Hagberg, Morgenstern et al. 1992; Chiang, Ko et al. 1993; Ghersi, Cavallaro et al. 1996; Ghersi, Cavallaro et al. 1996; Frost, Andersen et al. 1998; Gorsche, Wiley et al. 2002; Isolani, Bonfiglioli et al. 2002; Kim, Kim et al. 2004; Bonfiglioli, Farioli et al. 2008; Cartwright, Walker et al. 2012; Wyatt, Gwynne-Jones et al. 2013). A cross-sectional study using three clinic examinations was performed over the period 1982-1984 with follow up until 1985 on 377 workers in strenuous manual jobs and 338 workers in manually non-strenuous work in a large meat processing factory. The annual incidence of epicondylitis was greater in the strenuous job group, with11.3% for female packers and 6.4% for male meat cutters compared to 1% of workers in non- strenuous jobs, The annual incidence rate of injuries in the elbow was less than 1% of workers in non-strenuous jobs, 23.5% of female packers, 16.8% of female sausage makers and 12.5% for male meat cutters over the 12 months (Viikari-Juntura, Kurppa et al. 1991).

Lacerating injuries were particularly prevalent among meat processing workers (Lander, Sorock et al. 2010; Lander, Sorock et al. 2012). A study of the Midwest meat packing industry was conducted using Occupational Safety and Health Administration (OSHA) 200 injury and illness logs and First Reports of Injury from two plants from

1998-2000, with a total of between 2,449 and 2,682 workers per year. Laceration incidence rates were higher in the plant doing more slaughter and hide removal than the other plant over the three year period: 14.0 per 100, 11.5 per 100, and 8.3 per 100 full time workers, compared to 3.7 per 100, 4.8 per 100, and 3.0 per 100 full time workers respectively (Cai, Perry et al. 2005).

2.7 Factors associated with MSD

There are multiple risk factors that contribute to the occurrence of MSD in the workplace setting (Putz-Anderson, Bernard et al. 1997). Several studies have extensively examined the risk factors of MSD, which can be categorised into three general factors: psychosocial (e.g., overtime, job stress, depression, anxiety etc.), personal (e.g., age, gender, genetics, etc.), and physical working conditions, including biomechanical factors (e.g., repetition, force, etc.) (Marras, Cutlip et al. 2009; Ndetan, Rupert et al. 2009).These factors interact, they may exacerbate each other, and their effects may be mediated by cultural or societal factors. The following section will provide an overview of risk factors for MSD, mainly based on existing review articles.

2.7.1 Psychosocial factors

The first review (Bongers, De Winter et al. 1993) of the epidemiology literature on the relationship between psychosocial work factors and MSD was conducted in 1993. It concluded that lack of social support by colleagues, stress symptoms, repetitive work, high perceived workload, and time pressure are associated with MSD (Bongers, De Winter et al. 1993). There are several psychosocial factors that have been found to be associated with the incidence of MSDs, such as, repetitive movements, decision latitude, low workplace social support and job insecurity (Putz-Anderson, Bernard et al. 1997; Proto and Zimbalatti 2010), high psychosocial work demands and work stress (Da Costa and Vieira 2010), low job satisfaction, low job control, non-work-related stress, and high and low skill discretion (Bongers, De Winter et al. 1993; Hoogendoorn, van Poppel et al. 2000; Stansfeld and Candy 2006).

Several studies have identified a number of psychosocial factors associated with occurrence of MSD. For example, a 1-year prospective study conducted on 725 employees from different industry sectors aged 20–70 years, concluded that increased psychological job demands increased the probability of lateral and medial epicondylitis, and increased control (decision latitude) decreased the risk of carpal tunnel syndrome CTS (Bugajska, Zołnierczyk-Zreda et al. 2013). While strong evidence in the literature included a cohort or case–control studies reported that low social support, and low job satisfaction in the workplace were most frequently risk factors for onset back pain at work or private life (Hoogendoorn, van Poppel et al. 2000). Similar evidence supports the relationship between psychosocial risk factors such as work stressors and lack of social support at work and development of musculoskeletal problems among employees from industrial settings (Lang, Ochsmann et al. 2012).

A recent systematic review of 18 longitudinal studies that covered the literature until May 2009, also provides strong evidence for an incremental effect on the development of MSD from increased job demands, decreased job control, poor social support, and increased job strain: neck and/or shoulder disorders were the most frequently reported disorders among employees from industrial and service settings (Kraatz, Lang et al. 2013). This is consistent with previous findings from a large critical review of the epidemiologic literature of MSD factors, which identified that psychosocial work environment factors play a significant role in the etiology of musculoskeletal disorders of the upper extremity and back, which in turn produce increased muscle tension and increased hormonal excretion, that may exacerbate or worsen task-related biomechanical strain (Putz-Anderson, Bernard et al. 1997).

2.7.2 Personal factors

Musculoskeletal disorder rates for neck and upper limb disorders among women are high when compared to men both at work and outside of work (Hooftman, van Poppel et al. 2004; Nordander, Ohlsson et al. 2008; Messing, Stock et al. 2009). Barbosa and colleagues recently assessed the prevalence of upper-limb musculoskeletal pain in male and female workers identifying a higher prevalence of pain among women (24.1%), compared to men (11.0%) and argued that higher domestic workloads, and performing work tasks under highly physically demanding and poor environmental conditions resulted in the higher prevalence of musculoskeletal pain in females (Barbosa, Assunção et al. 2013). The suggested reasons why there are gender differences are that females appear to have a higher risk of musculoskeletal complaints due to awkward arm postures, in contrast to men who have a higher risk of musculoskeletal complaints due to lifting and hand-arm vibration (Hooftman, van Poppel et al. 2004). Similar differences have been found in prevalence of low back pain in the general population, with the prevalence of low back pain higher among female than males (35.3 % ±18.8 and 29.4 % ±18.5 respectively) (Hoy, Bain et al. 2012).

A cross-sectional study of 955 ammunition factory workers, found that 39.3% of workers reported symptoms of work-related MSD, with smoking (OR=1.372), chronic diseases (OR = 1.795), overweight (OR = 1.631), working year (OR =1.509), cold temperature (OR = 1.838), and work load (OR = 2.210) significant independent risk factors for occupational MSD (Pinar, Cakmak et al. 2013). Other studies have also identified overweight, obesity, and smoking as being associated with development of MSD across a wide range of populations (Al-Windi and Majeed 2010; Shiri, Karppinen et al. 2010; Shiri, Karppinen et al. 2010; Deere, Clinch et al. 2012; Paulis, Silva et al. 2014). However, there are differences in biological and psychosocial factors, and ability to influence work environments between men and women which may lead to differences in pain tolerance levels (Keogh 2006; Nunes and Bush 2012) that make women more likely to suffer from MSD. Evidence from laboratory experiments shows that women have higher pain sensitivity compared to men when exposed to the same risk factors (Rollman and Lautenbacher 2001; Racine, Tousignant-Laflamme et al. 2012).

2.7.3 Biomechanical factors

The physically demanding nature of work tasks such as awkward postures, repetitive, forceful, or prolonged exertions of the hands, frequent or heavy lifting, pushing, pulling, or carrying of heavy objects, often contributes to the high incidence of MSD within a wide range of workplace populations (Ketola 2004; Proto and Zimbalatti 2010; Jones and Kumar 2011; Colantoni, Marucci et al. 2012; Neupane, Miranda et al. 2013). For example, physical demands as a risk factor for MSD were investigated amongst physiotherapists and occupational therapists in Queensland, Australia. Approximately 67% reported symptoms of work-related MSD with the most frequently identified risk factors being biomechanical in nature, such as working postures and movements, and methods of lifting or carrying and repetitive movement. The study confirms that the symptoms of MSD may prevent physiotherapists and occupational therapists from achieving their capacity to continue working (Passier and McPhail 2011). This finding is supported by a systematic review which reported strong evidence that physical risk factors such as moving or lifting people or equipment, repetitive manual tasks, and work in awkward positions were associated with work-related musculoskeletal disorders in midwives, nurses, and physicians (Long, Johnston et al. 2012).

Electromyography (EMG) and self-report questionnaire were used to measure sustained trapezius muscle activity in three levels of activity, low 0-29%, moderate 30-49%, and high 50-100%, in order to predict the prevalence of neck and shoulder pain over a 2.5-year period in 40 adults with various work demands. Results showed that participants with a high level of sustained muscle activity had a rate of neck and shoulder pain three times higher than the low level group over a 2.5-year period (Hanvold, Wærsted et al. 2013). A recent meta-analysis has documented evidence supporting the relationship between workplace stressors and increased muscle activity in the neck–shoulder and forearm; yielding a statistically significant ($p < 0.01$) risk factor for developing pain (Eijckelhof, Huysmans et al. 2013).

A systematic review evaluated the results of 29 studies on occupational risk factors for shoulder pain and upper limb confirming repetitive movements, vibration, and duration of employment as risk factors for the development of upper limb MSD (Van Der Windt, Thomas et al. 2000). Another systematic review of 63 studies evaluated risk factors (biomechanical, psychosocial, or individual) for the development of work-related MSD. A reasonable level of evidence was identified for an incremental effect of excessive repetition, awkward static and dynamic working postures, heavy physical work, prolonged computer work and standing, and frequent heavy loads lifting and carrying, being associated with increased development of work-related MSD (Da Costa and Vieira 2010). This review and other studies that investigated risk factors of MSD reported that it was difficult to isolate these factors from each other, so there is no single factor that causes MSD: a combination of factors come together towards the development of MSD, (Kumar 2001; Punnett and Wegman 2004; Da Costa and Vieira 2010; Nunes and Bush 2012). Figure 4 illustrates the risk factor interaction for MSD proposed by Nunes and Bush (Nunes and Bush (2012).

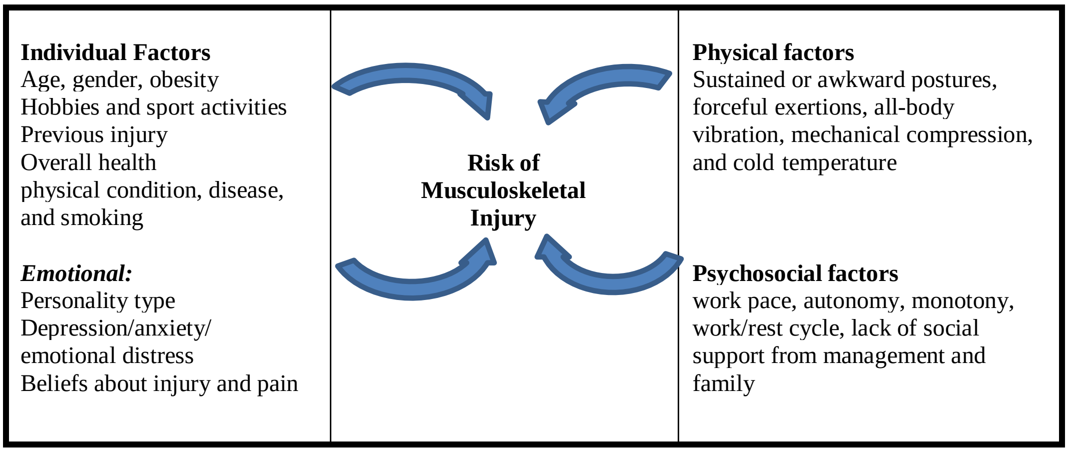

Figure 3: Main components of risk factors for musculoskeletal injury

2.8 Risk factors for MSD in meat processing

Meat processing tasks involve several occupational risk factors for MSDs including repetition, force and vibration, awkward and static postures (Frost, Andersen et al. 1998; Juul-Kristensen, Fallentin et al. 2002; Evangelista, De Fátima Tinoco et al. 2012), exposure to cold and wet climates (Piedrahíta, Punnett et al. 2004; Sormunen, Oksa et al. 2006; Buzanello and Moro 2012), and exposure to chemicals, and noise exposure (Tappin, Bentley et al. 2008). Literature reports that combinations of these exposures would likely increase the risk of incurring injury to nerves, tendons, muscles and supporting structures of the hands, wrists, elbows, shoulders, neck and low back (Gangopadhyay and Ray 2000; Tappin, Bentley et al. 2008; Mohammadi 2012).

In New Zealand, Tappin interviewed 237 workers in 28 plants (sheep, beef, veal, venison, and pork) over an 8 month period (Tappin, Bentley et al. 2008). A contextual factors model consisting of nine domains to assess internal and external factors covering biomechanical and psychosocial risk factors was used. The study reported that the most common risk factors were job demands and human resource issues, but interaction between all factors clearly existed (Tappin, Bentley et al. 2008). Psychosocial factors and MSD in meat workers were also investigated in France: high psychological demand at work was associated with increasing the risk of strain, decreasing production capacity, and was linked to poor perceived health in both males and females that increased with age (Cohidon, Morisseau et al. 2009).
Mohammadi (2012) also found psychosocial factors (intensified workload, low job control, low social support, and perceived monotony) and physical work factors (repetition, force, and postural work) were associated with increased incidence rate of

MSD for the neck (83.4%), elbows (70%), hands/wrists (68%), and shoulder (66%) over 12 months (Mohammadi 2012). The frequency of repetitive movements, recovery period, and problems caused by environmental stressors such as cold, heat, noise, chemical exposures, and work stress were associated with increased incidence rates of MSD, including both acute injuries and repetitive muscular strain injury (Németh and Balint 1991; Ghersi, Cavallaro et al. 1996; Ghersi, Cavallaro et al. 1996; Campbell 1999). Tension neck syndrome, tenosynovitis, and peritendinitis of the wrist and forearm , were also identified in hand-intensive, repetitive jobs, as were high incidence of hand/wrist cumulative trauma disorders (CTDs) (Viikari Juntura 1983) and fibromyalgia syndrome in the meat packing industry (Frost, Andersen et al. 1998; Marklin and Monroe 1998; Gallinaro, Feldman et al. 2001).

In addition, a systematic review of the associations of type of work, physical load factors, and psychosocial aspects of work with the occurrence of carpal tunnel syndrome (CTS) concluded that the occurrence of CTS was associated with jobs with high repetitive movements, and hand-arm vibration in the meat and fish-processing industry (van Rijn, Huisstede et al. 2009). Furthermore, physical load factors, and psychosocial aspects of work, were associated with occurrence of CTS and lateral epicondylitis in the same setting (van Rijn, Huisstede et al. 2009). A number of studies have independently identified an association between exposure to cold conditions with high repetition of hand movements and increased incidence of wrist disorders, elbow disorders, and carpal tunnel syndrome (CTS) among meat processing workers (Chiang, Chen et al. 1990; Kurppa, Viikari-Juntura et al. 1991; Griefahn, Mehnert et al. 1997; Sormunen, Oksa et al. 2006; Sormunen, Remes et al. 2009).

2.9 **Summary:**

These work-related factors that contribute to MSDs are known to impact on health-related quality of life, increase healthcare costs, and decrease daily activities as well as impact negatively on physical health in several ways (Bergman, Jacobsson et al. 2004; Winter, Brandes et al. 2010) It has also been reported that adults with MSD have an overall poorer health-related quality of life, and decreased daily activities compared to the general population who report no pain (Gureje, Von Korff et al. 1998; Bergman, Jacobsson et al. 2004; Mäntyselkä, Turunen et al. 2004). Reduction of these risk factors is the goal of most preventive approaches in the workplace setting to reduce the incidence and impact of MSD at the primary and secondary level. Many organizations are seeking to implement a variety of preventive ergonomic and occupational health strategies and programmes aimed to control and minimize the burden and the development of MSD. For example biomechanical, organizational, behavioural and personal interventions are commonly used approaches. Physical activity-based interventions are considered to be one of the most inexpensive approaches to increase the fitness and exercise capacity towards reducing the burden of musculoskeletal pain conditions on both individuals and society as well as an improvement of health-related quality of life (HRQL) as a positive impact for increasing physical activity. In the following chapter I will review recent, relevant evidence for the usefulness of physical activity interventions to prevent MSD and improve health-related outcomes.

3 Chapter Three

Physical activity, its importance, and how to measure it accurately.

3.1 Overview

Physical activity improves overall health and quality of life for all ages. Accurately quantifying physical activity is essential in assessing physical activity behaviour (Tudor-Locke and Bassett 2004). A variety of techniques have been used to measure physical activity in research studies (Laporte, Montoye et al. 1985; Ken-Dror, Lerman et al. 2005; Valanou, Bamia et al. 2006; Warren, Ekelund et al. 2010). This chapter will gather recent, relevant evidence for the usefulness of physical activity interventions for the prevention of chronic disease and improved health-related outcomes. Therefore, the purpose of this chapter is to provide a detailed description of the physical activity recommendations, health benefits of physical activity in general, and also examine previous research on step-count accuracy of physical activity monitors in free living and laboratory conditions.

3.2 Sedentary lifestyle

Physical inactivity and sedentary lifestyles including TV viewing, computer use, playing video games, and sitting time at work or school, are important risk factors for many chronic diseases. Many studies have demonstrated an association between physical inactivity and increased rates of chronic diseases including hypertension, cardiovascular disease, diabetes, obesity, and metabolic syndrome (Kokkinos, Sheriff et al. 2011; Cooper, Sebire et al. 2012; Edwardson, Gorely et al. 2012; Kushi, Doyle et al. 2012; Matthews, George et al. 2012; Van Der Ploeg, Chey et al. 2012; van Zyl, van der Merwe et al. 2012). The researchers concluded that sedentary lifestyles have become the most important public health challenge in developed countries. The economic burden of physical inactivity has increased to an estimated 1.5-3.0% of total direct health-care costs (Oldridge 2008); for example, the annual cost for direct health-care was £0.9 billion in the UK, $5.3 billion in Canada, and $24 billion in USA (Scarborough, Bhatnagar et al. 2011; Kohl, Craig et al. 2012). According to a World Health Organization (WHO) report in 2008, 31% of adults 15 years old and over exhibit a sedentary lifestyle, and have a 20-30% increased risk of mortality compared to active people. Physical inactivity is the fourth leading risk factor for mortality, accounting for 3.2 million deaths globally each year (World Health Organization 2011; Lee, Shiroma et al. 2012).

A survey conducted on US adults, aged 50-70 years, revealed that sedentary lifestyle behaviours such as prolonged television viewing and overall sitting time were positively associated with mortality after controlling for age, sex, education, smoking, diet, race, and moderately vigorous physical activity (Matthews, George et al. 2012). Other studies reported an association between sedentary behaviour, time spent on computer and TV watching, and all causes of mortality (Owen, Healy et al. 2010; Atkin, Adams et al. 2012; Ford 2012; Katzmarzyk and Lee 2012; Stamatakis, Hamer et al. 2012). The priorities of physical activity guidelines are to increase the levels of activity to achieve health benefits across the life span.

3.3 **Physical activity guidelines**

Physical activity is accepted as improving overall health and quality of life (Warburton, Nicol et al. 2006). Historically, there is painting evidence for physical activity being an important factor in maintaining the health and strength of soldiers in ancient Rome (MacAuley 1994). Since the middle of the last century, the benefit of physical activity leading to improved public health has been identified. In 1972, the American Heart Association (AHA) produced the first formal public health recommendation, titled "*Exercise testing and training of apparently healthy individuals: A handbook for physicians*" (American Heart Association 1972). This recommendation particularly focused on the beneficial impact of moderate to vigorous exercise on reducing risk for cardiovascular disease. Since the acceptance of these guidelines a number of other countries have also produced physical activity guidelines (Table 4) that have focused on improved health and reduction of risk for health disorders (Tremblay, Warburton et al. 2011; Australian Government 2014). The recommendations in these guidelines have marked similarity and although there are variances in types, frequency and intensity of activity the benefits of such interventions are particularly directed at improving health and reducing risk and reduction of the cost of health care.

In 1978 the American College of Sports Medicine (ACSM) also published the first form of public health recommendation on the amount and intensity of physical activity needed for developing and maintaining cardiorespiratory fitness by accumulating 15-

60 minutes of aerobic exercise, 3-5 per week (American College of Sports Medicine 1978). In 1995 the ACSM and the Centres for Disease Control and Prevention (CDC) published an update of a new public health recommendation stating that "*All adults should accumulate 30 minutes or more of moderate-intensity physical activity on most, preferably all, days of the week*". The recommendation focused on increasing physical activity, encouraging people with a sedentary lifestyle to become active in order get more health benefits. Brisk walking was recommended as one way to accumulate up to 30 minutes of moderate intensity daily physical activity (Pate, Pratt et al. 1995).

Table 4: Comparison of physical activity recommendations in different countries

Countries	Children 6-17 years of age	Adults 18-64 years of age	Older adults 65 years of age or older	References
USA	60 or more minutes of physical activity each day	At least 150 min a week or 75 min of vigorous activity each week	For 150 min each week or 75 min of vigorous activity each week	(Department of Health and Human Services 2008)
Canada	At least 60 min of moderate- to vigorous-intensity physical activity daily	At least 150 min of moderate- to vigorous-intensity physical activity per week, in bouts of 10 min or more	At least 150 min of moderate- to vigorous-intensity physical activity per week, in bouts of 10 min or more	(Tremblay, Warburton et al. 2011)
UK	For 60 minutes each day	At least 30 min of at least moderate-intensity physical activity a day, on 5 or more days a week.	In addition to adults, strength and balance activities two days per week	(Fiona Bull, Stuart Biddle et al. 2010)
Australia	At least 60 min of moderate to vigorous intensity physical activity every day	Accumulate 150 to 300 min of moderate intensity physical activity or 75 to 150 min of vigorous intensity physical activity each week	At least 30 min of moderate intensity physical activity on most, preferably all, days.	(Australian Government 2014)
NZ	60 min or more of moderate to vigorous physical activity	30 min of moderate intensity physical activity on most if not all days of the week	30 min of moderate intensity; or for 15 minutes vigorous intensity	(Ministry of Health 2001)

USA: The United States of America, UK: United Kingdom of Great Britain and Northern Ireland, and NZ: New Zealand

In 2007 physical activity recommendations (for adults aged 18-65 years) were updated (Haskell, Lee et al. 2007). The purpose was to clarify the 1995 recommendations for determining the type and amount of physical activity necessary to improve and maintain health outcomes. This update concluded:

- Adults aged 18-65 years old should accumulate a minimum of 30 minutes of moderate- intensity aerobic physical activity, on five days each week or vigorous-intensity aerobic physical activity for at least 20 minutes on three days per week, or a combination of moderate and vigorous-intensity activity.
- Moderate-intensity aerobic physical activity or equivalent should be performed for at least 10 minutes or more per bout.
- To increase or maintain muscular strength and endurance, exercise involving major muscle groups should be performed a minimum of two days per week.
- Adults who need further health benefits, to help reduce risk of chronic diseases should increase their activities to 300 minutes of moderate-intensity activity per week, or 150 minutes of vigorous-intensity aerobic physical activity (Haskell, Lee et al. 2007).

In older adults, 65 years old and above, and/or adults aged 50-64 years with clinically significant chronic conditions or functional limitation (regular medication needs, or impaired ability to carry out physical activity, respectively), separate recommendations were published by ACSM and AHA to illustrate the amount and types of physical activity that would improve functional health, and reduce the risk of chronic diseases (Nelson, Rejeski et al. 2007; Elsawy and Higgins 2010). The following recommendations were made:

- Older adults should accumulate at least 30 minutes of moderate-intensity aerobic physical activity five days per week or vigorous-intensity aerobic physical activity for at least 20 minutes on three days per week, or a combination of moderate and vigorous-intensity aerobic physical activity, to promote and maintain health.
- To increase or maintain muscular strength and endurance, older adults should perform physical activity involving resistance exercise for major muscle groups on at least two days per week.
- Participation in regular physical activity at least two days per week, reduced the risk of falls and improved balance (Nelson, Rejeski et al. 2007; Elsawy and Higgins 2010).

In 2008 the U.S. Department of Health and Human and Services (HHS) published comprehensive physical activity guidelines for Americans (Department of Health and Human Services 2008). The purpose of these guidelines was to provide information on the types, amount, and intensity of physical activity needed to promote and maintain health benefits, and reduce the risk of chronic diseases across the lifespan. The guidelines include all sectors and age groups of society: children and adolescents, adults, older adults, pregnant women, people with chronic diseases, and adults with disability. The general recommendation was for healthy and older adults to perform at least 30 minutes of moderate-intensity activity, five days per week, or vigorous-intensity physical activity for a minimum of 20 minutes, three days per week (or a combination of moderate and vigorous intensity physical activity). Older adults with chronic conditions unable to achieve the minimum recommendations for moderate intensity physical activity were advised to be as physically active as their abilities and conditions allowed. They were also advised to undertake physical activities twice weekly that involved muscle strengthening to improve balance and reduce the risk of falling (Department of Health and Human Services 2008).

Children and adolescents aged 5-17 years old should accumulate a daily minimum of 60 minutes moderate-to vigorous intensity physical activity, including muscle and bone strengthening, completed over three days per week. In order to achieve strengthening, children and adolescents should perform unstructured activities as part of an active lifestyle, involving playing, running, jumping rope, climbing - or through structured activities such as lifting weights and resistance exercises (Department of Health and Human Services 2008). In 2011 an update to the HHS 2008 recommendations was published. Current guidelines have recommended that every adult accumulate at least 150 minutes of moderate-to-vigorous intensity physical activity weekly, or 75 minutes per week of vigorous-intensity aerobic physical activity, or a combination of the two intensities to gain significant health benefits (World Health Organisation 2011).

The New Zealand Physical Activity Guidelines recommend adults should participate in at least 30 minutes of moderate activity on most, if not on all days of the week (Ministry of Health 2001). However, data from Sport and Physical Activity Surveys NZ

2008 (Sport and Recreation New Zealand 2008) showed that only 48.2 % of NZ adults were physically activity on five or more days per week, and a recent New Zealand Health Survey 2012 (Ministry of Health 2012), found that just 54% of adults met the current recommendations of daily physical activity. Physical inactivity is a significant public health issue in New Zealand (Lee, Shiroma et al. 2012) contributing significantly to non-communicable diseases and health problems, and costing approximately $1.3 billion annually (Market Economics Limited 2013).

3.4 Physical activity and public health

A number of studies have reported an association between increasing physical activity levels and improvements in the quality of life in the general population (Atalay and Cavlak 2012; Heath, Parra et al. 2012) and workplace setting (Conn, Hafdahl et al. 2009; Harding, Freak-Poli et al. 2013). Participation in physical activity has important benefits for reduced general risk of premature mortality across all groups and both sexes in the general population (Wen, Wai et al. 2011; Gulsvik, Thelle et al. 2012). In addition, evidence from a review of the literature reported that there is a relationship between increased physical activity and decreased risk of chronic conditions (Warburton, Charlesworth et al. 2010). Despite the evidence supporting the benefits of physical activity participation, globally 31% of adults still do not meet the physical activity recommendations (World Health Organisation 2011), causing a serious burden on healthcare expenditures. Those who do not undertake regular physical activity should consider increasing their activity to the recommended level, and while many different forms of activity are capable of meeting this recommendation, walking is considered to be an effective strategy, with little risk of injury in a low activity population (Siegel, Brackbill et al. 1995; Tudor-Locke, Craig et al. 2011). Evidence from a systematic review indicates that participation in sport activities increases psychological and social health benefits in adults (Eime, Young et al. 2013), including improved self-esteem, positive social interactions, and a reduction in levels of depressive symptoms. These authors suggest that team or group sports participation can have more health outcome benefits than individual activities. Promoting physical activity programmes among sedentary employees will likely lead to a reduction in public health concerns with Schröer and colleagues identifying significant improvements in physical activity, fitness, and weight in workplace settings that have incorporated physical activity programmes (Schröer, Haupt et al. 2014). This review also reported that interventions that focused on specific targets were more effective than multi-component intervention strategies.

It is very important to provide long-term physical activity programmes to prevent non communicable diseases (NCD) and reduce the burden of health-care costs. There is evidence for long-term effects of physical activity on the prevention of weight gain, obesity, coronary heart disease (CHD) and type 2 diabetes mellitus in healthy adults (Reiner, Niermann et al. 2013). This review included 15 longitudinal studies with at least 5-year follow up periods in healthy adult populations; four studies focused on weight gain and obesity, six studies focused on CHD, and five focused on type 2 diabetes mellitus. The authors concluded that most of these diseases result from sedentary lifestyles, but there was no evidence for an optimal doses of activity to improve health outcomes in the long term (Reiner, Niermann et al. 2013).

The elderly population (60 years and over) has an increased prevalence of chronic diseases, disability, and an increased need for medical intervention compared to other age groups (Etzioni, Liu et al. 2003; McGinnis and Moore 2006). These diseases can impact adversely on their psychological and social health behaviour. Research suggests that physical activity improves mental disorders including anxiety, social dysfunction, and depression in the elderly population (Cassilhas, Tufik et al. 2010; Lepan and Leutar 2012; Mortazavi, Mohammad et al. 2012). A longitudinal study over 11 years conducted in Taiwan, reported that decreases in baseline physical activity over the 11 year period were associated with corresponding rates of decline in cognitive performance (Ku, Stevinson et al. 2012).

Children and adolescents who participate in regular physical activity at school and during leisure time are more likely to require less health interventions in the future. Several studies have demonstrated that high levels of inactivity associated with a sedentary lifestyle place children and adolescents at increasing risk for obesity related-illnesses, cardio-metabolic disease, and type 2 diabetes (Ekelund, Luan et al. 2012; Rohana and Aiba 2012) in later life. In contrast, increasing physical activity levels was found to reduce the risk of many chronic diseases such as obesity related illnesses and cardio-metabolic disease (Sothern, Loftin et al. 1999; Strong, Malina et al. 2005; Janssen and LeBlanc 2010; Andersen, Riddoch et al. 2011; Friedrich, Schuch et al.

2012; Lavelle, MacKay et al. 2012; Verstraeten, Roberfroid et al. 2012). The majority of those studies recommended that children should accumulate 60 min of moderate to vigorous activity every day to achieve health benefits in the short and long term.

3.5 Physical activity and chronic disease prevention

3.5.1 Type 2 diabetes

The effect of physical activity on reducing risk of developing type 2 diabetes has been consistently established by several prospective and controlled trials including either aerobic or resistance exercise programmes (Pan, Li et al. 1997; Tuomilehto, Lindström et al. 2001; Hsia, Wu et al. 2005; Jeon, Lokken et al. 2007; Balducci, Zanuso et al. 2009; Umpierre, Ribeiro et al. 2011). Most of the studies support moderately intense activity over 5 days helping to improve glucose control, blood lipid levels, insulin resistance, blood pressure, and weight reduction (Laaksonen, Lindstrom et al. 2005; Jeon, Lokken et al. 2007), as well as reducing the risk of all-cause mortality (Balducci, Zanuso et al. 2009; Penn, White et al. 2009; Umpierre, Ribeiro et al. 2011; Yavari, Najafipoor et al. 2012) with an estimated 28-58% reduction in the incidence of type 2 diabetes (Knowler, Barrett-Connor et al. 2002; Fernández 2007; Li, Zhang et al. 2008; Penn, White et al. 2009) after follow-up, ranging from 2.8 years to 7 years of active intervention.

3.5.2 Cancers

Regular physical activity accumulating at least 30 min of moderate-intensity activity a day (Miles 2008; Thompson 2010) has been associated with a reduced risk of colon, prostate and breast cancers (Kruk and Aboul-Enein 2006; Moore, Gierach et al. 2010; Anzuini, Battistella et al. 2011; Loprinzi, Cardinal et al. 2012). The authors found a 13-20% estimated reduction in the incidence of cancers as a result of changes in some hormone levels. Long term physical activity that is undertaken from early childhood until later-life has the greatest effect on reduction of cancers risk (Miles 2007). Regular physical activity has also been linked to a reduced risk of cancer-related mortality and improved quality of life following a formal cancer diagnosis (Barbaric, Brooks et al. 2010; Anzuini, Battistella et al. 2011).

3.5.3 Overweight and obesity

Overweight and obesity are highly prevalent chronic health conditions in the developed world affecting approximately 1.4 billion adults, and more than 40 million children under the age of five in 2010 (World Health Organization 2011). They are associated with 44% of diabetes, 23% of ischemic heart disease, and between 7% and 41% of certain cancers (World Health Organization 2011). Furthermore, the National Health and Nutrition Examination Survey (NHANES) reported that the prevalence of obesity was 35.5% (95% CI, 31.9%-39.2%) for adult men and 35.8% (95% CI, 34.0%-37.7%) for adult women from 1999 to 2010 (Flegal, Carroll et al. 2012). Physical activity is accepted as a key factor in modifying the behaviour of obese individuals (Boreham 2006; Ismail, Keating et al. 2012), and a number of studies have found high levels of physical activity are associated with reduced risk factors for obesity (Boreham 2006; Harrington, Tudor-Locke et al. 2011; Jakicic, Otto et al. 2011; Ismail, Keating et al. 2012; Milanovic, Pantelic et al. 2012). A combination of physical activity (either aerobic or resistance training) and diet have been found to be important short and long term strategies for weight loss in middle aged people 40-64 years (Milanovic, Pantelic et al. 2012). Prospective studies have reported that moderate to vigorous physical activity can reduce obesity and risk of chronic disease in obese individuals (Britton, Lee et al. 2012; Katzmarzyk and Lear 2012), with a decreased risk of metabolic syndrome from 30-40% in general populations (Physical Activity Guidelines Advisory Committee 2009).

3.5.4 Musculoskeletal disorders

The benefits of physical activity as management and prevention strategies for people suffering from different musculoskeletal disorders (MSDs) are generally well accepted (Proper, Koning et al. 2003). Walking as a form of physical activity has been shown to have a role to play in the management of populations with MSD, including LBP, osteoporosis, hip, and knee osteoarthritis (Talbot, Gaines et al. 2003; Roddy, Zhang et al. 2005; Hurley, O'Donoghue et al. 2009; Hartvigsen, Mors et al. 2010; Ng, Heesch et al. 2010; McDonough, Tully et al. 2013). A study by Hartvigsen. et al (2010) found that Nordic walking for patients with chronic LBP of more than eight week duration was generally effective for reducing pain and improving health related outcomes. Another study reported that a pedometer-based walking intervention was an effective strategy for reducing back pain and improving physical function (McDonough, Tully et al. 2013). The study examined the feasibility of a pedometer walking programme on reducing chronic low back pain (CLBP) at eight weeks on 57 patients; levels of disability (Oswestry Disability Questionnaire ODQ) decreased by -5.5 points (95% CI,

-8.8 to -2.2) for the intervention group compared with participants assigned to the control group (-1.0, 95% CI, -7.6 to -5.6) (McDonough, Tully et al. 2013). Furthermore, there is consistent evidence from various literature reviews that walking and physical exercise are beneficial in order to reduce pain and improve health outcomes in the short term for people with LBP (Vuori 2001; Henchoz and Kai-Lik So 2008; Hendrick, Wake et al. 2010). In contrast, some studies show participation in sporting activities that involves twisting, pulling, and intense physical activity may increase the risk of developing LBP (Heneweer, Staes et al. 2011).

People with knee and hip OA may have a fear of worsening disease progression when participating in physical activity. However, many studies have demonstrated that various types of physical activity such as aerobic fitness or resistance and endurance training are effective in the management and treatment of people with knee and hip OA (Hernández-Molina, Reichenbach et al. 2008; Fransen and McConnell 2009; Keysor and Heislein 2010; Pisters, Veenhof et al. 2010; Esser and Bailey 2011; Semanik, Chang et al. 2012). Participation in physical activity of moderate intensity exercise three to five times per week has been shown to decrease pain and disability and improve function and improve quality of life in people with knee and hip OA (Ettinger Jr, Burns et al. 1997; Lundebjerg 2001; Penninx, Messier et al. 2001; Fransen, McConnell et al. 2003; Talbot, Gaines et al. 2003; Roddy, Zhang et al. 2005; Fontaine and Haaz 2007; Li, Zhang et al. 2008; Ng, Heesch et al. 2010). Furthermore, participation in physical activity has also been found to increase or maintain muscle mass, power, and strength in men and women of all ages (Karlsson 2004; Kirk, Washburn et al. 2007; Ferreira, Sherrington et al. 2012), as well as increasing bone density and reducing hip fractures in the general population (Karlsson 2002; Karlsson, Nordqvist et al. 2008; Babatunde, Forsyth et al. 2012) which resulted in better quality of life outcomes and higher levels of performance in quantified daily living activities. Epidemiological studies have shown a reduction of risk hip fracture ranging from 3.6 to 6.4 % (Babatunde, Forsyth et al. 2012), osteoarthritis from 22-80 % (Physical Activity Guidelines Advisory Committee 2009), and falls in older people from 30-50% (Paterson and Warburton 2010) among active people compared with low activity populations.

A summary of systematic reviews highlighted the high frequency of musculoskeletal problems in workplace setting (Hayes, Cockrell et al. 2009; Osborne, Blake et al. 2012). Most systematic reviews have connected workplace physical activity interventions with enhanced management of MSD among employees (Proper, Heymans et al. 2006; Verhagen, Karels et al. 2007; Kuoppala, Lamminpää et al. 2008; Bell and Burnett 2009; Coury, Moreira et al. 2009; Sihawong, Janwantanakul et al. 2011). A systematic review (Sihawong, Janwantanakul et al. 2011) of nine randomized controlled trials (in total 1594 patients) assessed the effectiveness of exercise for prevention of nonspecific neck pain in office workers, reporting strong evidence for various kinds of exercises (muscle strengthening and endurance exercises) in treating workers with neck pain. Moderate evidence supported the use of muscle endurance exercise in reducing pain-related disability. An effective programme should include muscle strengthening and/or endurance exercises performed in 1-3 sets of 5-20 repetitions, 3 to 5 times a week over a period of 15 weeks to 12 months. A critical review by Propper and colleagues that included 26 randomized and non-randomized controlled trials, identified strong evidence for the benefit of worksite physical activity to manage MSD and increase physical activity levels among employees (Proper, Koning et al. 2003). This review used a qualitative method and reported that 23% (6/26) of studies included in the review had a high methodological quality. A further review has also revealed evidence for associations between physical activity during leisure time and musculoskeletal symptoms in worker populations (Hildebrandt, Bongers et al. 2000).

3.6 Physical activity measurements

Physical activity is a complex and multifaceted behaviour, which is difficult to measure accurately (Valanou, Bamia et al. 2006; Warren, Ekelund et al. 2010). There are more than 30 different techniques which have been used to measure physical activity in research studies (Laporte, Montoye et al. 1985; Warren, Ekelund et al. 2010). Choosing the best method depends on several factors such as size of the study, age of the population, and the purpose of the study (Vanhees, Lefevre et al. 2005) as well as reliability and validity of the instruments (Laporte, Montoye et al. 1985). A series of comprehensive reviews of physical activity assessments have described various methods for measuring physical activity within a wide range of populations (Montoye and Taylor 1984; Laporte, Montoye et al. 1985; Meijer, Westerterp et al. 1991; Dale, Welk et al. 2002; Ken-Dror, Lerman et al. 2005; Valanou, Bamia et al. 2006; Corder, Ekelund et al. 2008; Reilly, Penpraze et al. 2008; Warren, Ekelund et al. 2010). These methods can be grouped as follows: objective methods such as activity monitors; double labelled water (DLW), indirect calorimetry, pedometers, and heart rate monitors, as well as subjective self-report methods such as physical activity diaries, logs, recalls interviews, and questionnaires. Each measurement method has specific advantages and disadvantages, which are presented in Table (Dale, Welk et al. 2002; Vanhees, Lefevre et al. 2005).

Table 5: Physical activity assessment methods

Method	Advantages	Disadvantages
Self-report	Quantitative and qualitative information Simple and inexpensive	Reliability and validity problems Recall error, misclassification of activity
Activity monitors	Objective, laboratory and free-living setting Indication of intensity of the movement Ease of data collection and analyses	Expensive for large sample Time-consuming, impractical for assessing physical activity patterns in large population
Heart rate Monitors	Free-living /Laboratory Non-invasive, extended wear- time capability Easy of data collection and analyses Indication of intensity of the movement	Accuracy, reliability low/high heart rate Expensive for large sample
Motion sensors Pedometer Accelerometer	Objective, laboratory/free-living Simple and inexpensive Extended wear-time capability	Inability to capture incline, often do not account for individual differences
Direct observation	Quantitative and qualitative information Software for data collection and analyses	Time and labour intensive May alter normal physical activity behaviour
Indirect calorimetry Doubly labelled water	Accurate, reliable Ability to assess energy of expenditure	Time and labour intensive Invasive High cost

Source: (Dale, Welk et al. 2002; Vanhees, Lefevre et al. 2005).

3.6.1 International Physical Activity Questionnaire (IPAQ)

Assessing physical activity in large populations by subjective tools is a useful means to explore the effect of inactivity on the outcome of chronic diseases (Prince, Adamo et al. 2008). Epidemiological studies using these techniques have demonstrated that physical inactivity contributes to increased risk of premature death (Booth, Roberts et al. 2012; Kohl, Craig et al. 2012; Lee, Shiroma et al. 2012) and is positively associated with an increased risk of a number of chronic diseases including metabolic syndrome, type 2 diabetes, hypertension, cardiovascular disease, and obesity (Kokkinos, Sheriff et al. 2011; Edwardson, Gorely et al. 2012; Matthews, George et al. 2012; van Zyl, van der Merwe et al. 2012). In order to better inform the prevention and management of chronic diseases, accurate assessment of physical activity level is required. A large number of physical activity questionnaires, such as self-administered questionnaires, international physical activity questionnaires, physical activity diaries, self-reported leisure-time physical activity questionnaires, and the Minnesota leisure time physical activity questionnaire, have been developed which focus on different populations (Craig, Marshall et al. 2003; Admo et al. 2009). These measures are frequently used due to their practicality, low cost, low participant burden, and general acceptance (Admo et al. 2009). The self-report methods are often beset with issues of recall and response bias and the inability to capture the absolute level of physical activity (Craig, Marshall et al. 2003; Lee, Macfarlane et al. 2011). The reliability and validity of the IPAQ and other physical activity questionnaires to measure habitual activity in free living conditions were investigated. Correlations between self-report and direct measures were generally low-to-moderate and ranged from (−0.56 to 0.89) in a young populations (Admo et al. 2009). However, the International Physical Activity Questionnaire (IPAQ) is the most commonly used tool to assess physical activity in the general population (Craig, Marshall et al. 2003). It is easily completed within five minutes (Craig, Marshall et al. 2003; Kurtze, Rangul et al. 2008; Oyeyemi, Oyeyemi et al. 2011; Tomioka, Iwamoto et al. 2011; Chun 2012) and was developed as an instrument (self-reported) to measure health-related physical activity in populations among 18- 65 year-olds. The short form consists of seven items providing information within various intensity levels including vigorous-intensity (e.g. aerobic activities), moderate-intensity (e.g. cycling activities), walking activities and sitting time in the last seven days (Craig, Marshall et al. 2003; Lee, Macfarlane et al. 2011). Several international studies have tested the reliability and validity of the IPAQ. In 2003 the reliability and validity of the IPAQ was assessed in 12 countries against accelerometers for adults aged 18 to 65 years and for both short and long versions of the IPAQ (n=1974). Test-retest reliability of the same version was conducted within 8 days and 10 days for both short and long versions respectively, while the validity measure was conducted by comparing data from IPAQ with data from an accelerometer, and also comparing data between different forms of administration (telephone, self-administration) in the same version. Results founds that IPAQ is acceptable for research studies, as the questionnaire has good test retest reliability coefficients (around Spearman's r of 0.81 for the long version and 0.76 for the short version), while validity assessed against the accelerometer demonstrated moderate Spearman's r = 0.30 and 0.33 for short and long versions respectively (Craig, Marshall et al. 2003).

A systematic review (Lee, Macfarlane et al. 2011) of 23 studies assessed the validity of IPAQ-SF (short form) against different instruments, reporting similar Spearman's correlation coefficients (0.28) between the IPAQ-SF in total physical activity and objective tools (pedometers, accelerometers, and fitness measures), indicating only weak evidence for the ability of the IPAQ-SF to assess physical activity correctly. They concluded that IPAQ-SF overestimated physical activity by 84% which might be because it did not reach the minimal acceptable standard (effect sizes) in the clinicians' studies for self-administrated physical activity questionnaires for adults which are set at 0.50 and 0.40 for objective devices and fitness measures respectively(Ferguson 2009; Terwee, Mokkink et al. 2010; Van Poppel, Chinapaw et al. 2010). In this review the majority of studies did not report absolute scores or standard deviations and thus the effect size for difference in findings between the IPAQ-SF and objective physical device could not be computed.

Van Der Ploeg and colleagues conducted (2010) a comparative study in nine countries of the IPAQ-SF for assessing walking against seven days of accelerometer data. The total time walked per week ranged from 150 to 210 minutes across the subjects in the nine countries studied. Test-retest reliability (Spearman correlation coefficients) for the walking question resulted in a three-day test retest score ranging from 0.69 to 0.91 and a seven day score of 0.71. Testing the IPAQ-SF against accelerometers obtained a Spearman correlation that ranged from 0.18 to 0.39 and a Spearman correlation ranging from 0.04 to 0.24 for walking and for moderate physical activity. Thus the validity coefficients for walking activity can be considered fair to modest correlations and stronger than for other activities, including nonwalking moderate to vigorous intensity physical activities (Van Der Ploeg, Tudor-Locke et al. 2010).

Another systematic review and meta-analysis (Kim, Park et al. 2013) evaluated the convergent validity of the IPAQ across several languages. The results showed positive relationships between IPAQ and other instruments across all components of the questionnaire. Effect size ranged from Cohen’s 0.27- 0.49, with medium size for walking (ES=0.32) and small size for moderate activity (ES=0.27); no statistically significant differences were found in terms of language of IPAQ for any physical activity categories (Kim, Park et al. 2013). The Spearman correlation ranged from 0.15 to 0.26 for total weekly time spent doing physical activity when assessed against the accelerometer and pedometer (seven days data). Reliability between the two administrations of the IPAQ ranged from 0.71 to 0.89 within the university setting (Dinger, Behrens et al. 2006). Overall, the IPAQ-SF has been recommended for population prevalence studies as it has been validated and confirmed as reliable for monitoring population levels of physical activity in different socio-cultural contexts. These results show moderate correlation ranging from r=0.18-0.39 between reported and other physical activity measures, which confirms that IPAQ can monitor adults in diverse settings (Craig, Marshall et al. 2003; Kim, Park et al. 2013).

3.6.2 Accelerometers

Accelerometers are devices that are able to assess the accelerations of movement and record the pattern of physical activity (intensity, frequency, and duration) over time (Corder, Brage et al. 2007). There are different commercial brands of accelerometers available on the market for the objective assessment of physical activity in population groups (Feito, Bassett et al. 2012; Strath, Pfeiffer et al. 2012). They have been used successfully in intervention trials to measure free living physical activity in children (Metcalf, Henley et al. 2012), and have also been used to describe and measure the pattern of physical activity in both adult and elderly populations (Bento, Cortinhas et al. 2012). It is important to define the level of physical activity in patients with chronic diseases in order to better design optimal intervention programmes for health benefits. The most commonly used devices in research to assess physical activity are piezoelectric accelerometer sensors such as ActiGraph, Actical (Mini Mitter Co, Inc, Bend, Oregon), and RT3 (StayHealthy, Inc; Monrovia, California) (Lyden, Kozey et al. 2011).

Accelerometers have advantages and disadvantages but unlike pedometers, they are better at measuring intensity of activity, energy expenditure, inactive time, and can store data for more than seven days (Chen and Bassett Jr 2005; Corder, Brage et al. 2007). The main disadvantage is requiring staff time to process and analyse data with appropriate hardware and software as well as the expense per unit cost ($450-$600) (Dale, Welk et al. 2002; Chen and Bassett Jr 2005; Masse, Fuemmeler et al. 2005).

3.6.3 Pedometers

Pedometers are motion-sensor devices that have been widely used as an objective tool to assess walking-related physical activity by recording the number of walking steps, distance travelled, and an estimate of energy expenditure in different populations (Lubans, Morgan et al. 2009); they have also been used as motivational tools to increase ambulatory physical activity levels in sedentary populations (Hillsdon 1996; Baker, Mutrie et al. 2008; Valentine, Whigham et al. 2009; Gardner and Campagna 2011). Pedometers are popular for studies on both children and adults as they are relatively inexpensive and easy to use by being worn on the waist at the midline of the thigh. Walking, as a form of physical activity, has been quantified as the number of steps per day or distance travelled, and several studies have translated that 30 min of brisk walking produces 3100 to 4000 steps, depending on the age and health conditions of the population (Welk, Differding et al. 2000; Harrington, Tudor-Locke et al. 2011; Tudor-Locke, Craig et al. 2011). However, it is important to determine the accuracy of pedometers before they are used in research.

3.6.3.1 Accuracy and reliability of pedometers

Several models of pedometer are available and have been employed in a variety of different studies. Several recent studies have been conducted to examine the validity and reliability of various pedometers under a variety of conditions to define measurement accuracy in adult populations.

3.6.3.1.1 Free-living conditions

Bassett and colleagues assessed the accuracy of five brands of electronic pedometers (Freestyle Pacer, Eddie Bauer, L.L.Bean, Yamax, and Accusplit), in 20 adults aged from 18 to 65 years, walking a 4.88 km sidewalk course under three conditions (sidewalks, walking speed, and track surface) (Bassett Jr, Ainsworth et al. 1996). Participants wore two of the same pedometers on both the right and left sides of the body. The Yamax Digi-walker was found to be the most accurate pedometer in counting steps; recording only 1% difference between two units of the same brand, with greater accuracy at walking speed of 80-107 $m \cdot min^{-1}$. Schneider et al. (2004) compared thirteen models of pedometers on 20 adults (10 male, and 10 female) under free-living conditions over a 24 hour period. The Yamax Digi-walker DW-200 (DW200) was selected as a criterion and worn on the left side of the body to compare other models on the right side over 13 days. Results reported that the DW200, Kenz Lifecorder (KZ), New-Lifestyles NL-2000 (NL), and DW701 were the most suitable for research purposes, with all giving similar mean values for steps per day compared with DW200. These results provide strong evidence for the accuracy of the Yamax Digi-walker series pedometer when compared to other brands. Schneider and colleagues also conducted a study to evaluate the accuracy and reliability of 10 pedometers (Yamasa Skeletone (SK), Sportline 330 (SL330) and 345(SL345), Omron (OM), DW 701, KZ, NL, Oregon Scientific (OR), Freestyle Pacer Pro (FR), and Walk4Life LS 2525 (WL)) over a 400 meter walking track walking at each individual's normal speed. A total of 20 adults each wore the same brand of pedometers on both the right and left sides of the body while the researcher walked behind them to accurately record their pace. Results reported that the mean values of eight pedometers were not significantly different from the steps recorded by the researchers. The most accurate pedometers were KZ, NL-2000, and Digi-Walker which counted the actual steps taken within ±3% (513 steps during 400m) and 95% of the time with >0.99 reliability. These pedometers (KZ, NL-2000, and DW) are considered appropriate for use to accurately measure physical activity in research studies (Schneider, Crouter et al. 2003).

3.6.3.1.2 Laboratory conditions

Tudor-Locke and colleagues evaluated 15 step counters (*Kellogg's* Special K*;* K pedometers; manufactured for Kellogg Canada by Sasco, Inc.) and nine Yamax brands (Yamax Corp., Tokyo, Japan) during treadmill walking at 80 $m \cdot min^{-1}$, driving a motor vehicle over a set course, 20 step test and 24 hours free-living conditions in nine subjects (Tudor-Locke, Sisson et al. 2006). The Yamax pedometers had less than 5% error in the 20 step test, and recorded 3.9±6.6% Mean Absolute Present Error (MAPR) of actual steps vs. 24.2±33.9% for step counters during treadmill walking. The Yamax pedometers were more accurate during free-living conditions, according MAPR of 19.5±21.2% vs. 44.9±34.5% for step counters relative to the ActiGraph accelerometer. These findings support the use of Yamax pedometers for physical activity research studies. Crouter et al. (2003) evaluated the accuracy and reliability of 10 pedometers at different walking speeds worn by 10 subjects walking on a treadmill in five minute stages. Of the 10 pedometers, six (Yamasa Skeletone, Omron, Yamax DW, New-Lifestyles NL-2000, Kenz Lifecorder, and Walk4Life LS 2525) provided the same mean values within ± 1% of the actual steps taken at speeds 80 $m{\cdot}min^{-1}$and above. Most pedometers were not accurate at slow speeds (54 and 67 $m{\cdot}min^{-1}$) except four pedometers (WL, KZ, NL, and DW) that were most accurate at slow speeds. Overall, Yamax DW pedometers were the most accurate pedometers providing actual step count, distance, and a relatively accurate estimate of gross kilocalories for walking.

Overall, the pedometers were assessed through the free living, and controlled conditions under different walking speeds. The results of these studies reported that walking speed affected pedometer accuracy. For example, all brands under-reported actual steps at slow speeds (54, and 67 $m{\cdot}min^{-1}$) which may by due to the mechanics of the pedometer such as the sensitivity that required an acceleration of at least 0.30 g to register a step (Tudor-Locke, Williams et al. 2002; Tudor-Locke, Williams et al. 2004). Also, the results suggest that pedometer accuracy improves at moderate and fast walking speeds (80-107 $m{\cdot}min^{-1}$). The maximum acceptable error for miscounting steps is 3%, nominated by Japanese Industrial standards as set by the Ministry of Industry and Trading regulations (Hatano 1993). All accurate pedometers described above were made in Japan and met this standard. Yamax Digi-Walker (DW) pedometers were identified as the most accurate among them. Table 6 presents the data for the different pedometer brands and models under different conditions.

Table 6: Summary of different pedometers

Study	Pedometers	Condition	Results
(Bassett et al. 1996)	Freestyle Pacer 798 (FR, Camarillo, CA, USA) Eddie Bauer Compustep II(Redmond, WA, USA) Yamax Digiwalker DW-500 (Tokyo, Japan) LL Bean Pedometer (Freeport, ME, USA) and LL Bean Pedometer (Freeport, ME, USA)	Free living right and left sides	Recorded 95.05% of actual steps (mean of left and right pedometers) Recorded 92.8% of actual steps (mean of left and right pedometers) Recorded 100.65% of actual steps (mean of left and right pedometers) Not recorded
(Schneider, et al. 2004)	Colorado on the Move (CO, USA), Sportline 345 (SL 345, Taiwan), Yamax Skeletone EM-180 (SK, Japan), Freestyle Pacer (FR,USA), and Accusplit (AC). Omron HJ-105 (OM, China), Oregon Scientific PE316CA (OR, China), Walk 4Life LS 2525 (WL, Taiwan), Kenz Lifecorder (KZ,Japan), New-Lifestyles NL-2000(NL, Japan), Sportline 330 (SL 330, Taiwan), Yamax Digi-Walker DW-200 (DW-200, Japan), and Yamax Digi-Walker DW-701 (DW-701, Japan)	Free living, right and left sides	Significantly underestimated steps $P<0.05$ compared with the criterion DW-200 Significantly overestimated steps $P<0.05$ compared with the criterion DW-200 Similar step values compared with the criterion DW-200
(Schneider, et al. 2003)	DW 701, KZ, and NL pedometers Oregon Scientific PE316CA (OR, China), and Sportline 330 (SL 330, Taiwan) WL, SK, SL 345, FR, and OR pedometers	Free living right and left sides	Recorded high reliability (>0.99) and accuracy within ±3% of the actual steps. Significantly $P<0.05$ overestimated and underestimated respectively Least accurate recordings; within ± 188 of the actual steps.
(Tudor-et al. 2006)	15 (*Kellogg's* Special K*;* K pedometers; manufactured for Kellogg Canada by Sasco, Inc.) and 9 Yamax brand (Yamax Corp., Tokyo, Japan)	20 steps test Non-stepping(motor vehicle) Controlled conditions Free living	53% of K pedometers showed greater than 5% error compared to 3.9 % error of actual steps for Yamax K pedometers detected <1 non-steps per km driven compared to <0.5 non-steps detected by Yamax K pedometers recorded 24.2% mean absolute error compared to 3.9% for Yamax K pedometers recorded 44.9% mean absolute error compared to 19.5% for Yamax relative to the ActiGraph accelerometer
(Schneider; et al. 2003)	(SK, OM, DW, NL, KZ, and WL) pedometers FR, SL 345, SL 330, and SK pedometers SL330, SK, OM, DW, KZ, NL, FR, and WL pedometers	Controlled conditions right and left sides	Recorded mean values within ± 1% of actual steps at speeds of 80 $m \cdot min^{-1}$ and above. DW pedometer did non-significantly differ between actual steps and at any speeds $P<0.05$. Recorded a significant underestimation of actual steps $P<0.05$. 80% of pedometers exceeded 0.81 correlation coefficients between the right and left sides.

3.6.4 Yamax Digi-Walker DW200

The DW200 has been widely used in different populations to evaluate the accuracy of step counts under different conditions and populations. This review will summarize the accuracy of the DW 200, which will be used in this study under different conditions and all age groups.

Figure 4: Yamax Digi-Walker DW200

Note: Image obtained from http://www.yamax.com.au/

3.6.4.1 Free-living conditions

The DW 200 pedometer is a low cost tool costing about $30 to measure physical activity and is easy to use across all populations. It has a spring-levered arm, which moves up and down to register movements in the vertical accelerations during activity (Tudor-Locke, Williams et al. 2002; Vanhees, Lefevre et al. 2005). This feature was unable to measure some activities correctly such as upper body activity, swimming, cycling, and carrying loads, and it could not provide information about the patterns of physical activity (intensity, frequency, and duration). Based on the previous studies, the DW 200 pedometer was commonly used for assessment of stepping rate across all populations. For example, a study by Vincent and Sidman (2003) tested measurement error in 24 DW200 pedometers on 11 adults (eight female, three male; ages 27-54) in a series of trials over100 steps while wearing four pedometers (two on each side) on six occasions until each subject had worn all 24 pedometers. In addition, this group performed two trials of the ‘shake test’ in the laboratory (pre-post-test). Pedometers were placed in the shake test box, and the box was moved 100 times to record the number of steps taken on each pedometer. There was a 5% non-significant error in both pre-test and post-test indicating that the DW200 is acceptable and accurately counts steps for research purposes in the adult population. It is important to detect the accuracy of DW200 over an entire year, where seasonal variation may affect the functioning of the unit. Kang and colleagues examined the accuracy of DW200 steps count over 365 consecutive days on 23 adults. To provide accurate results 10 samples of step count were taken for each month and season (over 2, 3, 4, 5, 6, 7, 8, 9, and 10 days). Results revealed that the MAPR between seasons were slight, and thus the DW200 can provide accurate steps count during the whole year in adult populations (Kang, Bassett et al. 2012).

Overweight and obesity are becoming a public health crisis in the developed world affecting over 1.4 billion adults, with an estimated 35% prevalence of obesity among adults in 2010 (World Health Organization 2011; Flegal, Carroll et al. 2012). The WHO has defined overweight as a BMI of 25.0kg/m^2 to 29.9kg/m^2 and obesity as a BMI greater than or equal to 30.0kg/m^2 (World Health Organization 2011). The accuracy of pedometers may also be affected with obesity by inappropriate placement or by reducing the force of vertical accelerations. A study by Tyo, Fitzhugh et al (2011) compared the accuracy of DW200 and NL 2000 with StepWatch used as criterion device under free-living conditions over seven consecutive days, in adults of all weight categories (normal, overweight and obese). This study reported that both pedometers recorded fewer step counts than the criterion device StepWatch across all weight categories (p=0.001), and both pedometers recorded similar error for the normal and overweight categories, but in the obese and slow speed categories, the DW 200 recorded more error than NL 2000. Furthermore, the accuracy of DW200 in young children was also examined in 24 children over five consecutive days in the outdoor environment and compared with an accelerometer and with direct observation (Hands, Parker et al. 2006). The DW200 was more accurate than the accelerometer based on direct observation: whereas there was a strong 0.90 correlation between the DW 200 and the actual step count, the correlation with accelerometer data was only 59%. Similarly, another study (Beets, Patton et al. 2005) also found a high agreement of more than 98% between actual step counts and the DW200; the absolute value of the present error of steps was no greater than 0. 9% during treadmill walking.

3.6.4.2 **Laboratory conditions**

The accuracy of the DW200 has been assessed during laboratory studies at different ambulatory speeds and in different populations to compare concurrent accuracy with free living conditions (Motl, McAuley et al. 2005; Grant, Dall et al. 2008). For example, Le Masurier and Tudor-Locke (2003) conducted two studies to compare the accuracy of the DW200 and the CSA Actigraph accelerometer under different walking speeds on the treadmill, and during non-stepping (motor vehicle) on paved roads. Participants walked at five different speeds (54, 67, 80, 94, and 107 $m \cdot min^{-1}$) in 5 minute stages, and travelled about 32.6 km by motor vehicle. Both motion sensors were accurate at a speed of 67 m. $min\text{-}^{1}$ and above, with no significant difference between instruments compared with the actual steps taken for each speed. However, both erroneously detected steps while driving a vehicle, in that on average the accelerometer detected approximately 250 such steps compared to 15 steps for the pedometer. This study suggested that both motion sensors are suitable for research studies. Walking is considered as one of the most accessible form of physical activity for all ages, and is especially important for older adults (Ogilvie, Foster et al. 2007; Tschentscher, Niederseer et al. 2013; Mobily 2014). Older adults face different health problems including mobility limitations, obesity, type 2 diabetes, and arthritis (Wu, Guo et al. 2013; Buja, Damiani et al. 2014; Sibley, Voth et al. 2014; Sibley, Voth et al. 2014) that may affect the accuracy of DW 200. A study of older adults (Grant, Dall et al. 2008) examined the accuracy of the DW200 and NL 2000 pedometers and the activPAL accelerometer, in measuring the step number and cadence on a treadmill at five speeds and outdoor walking at three speeds (slow, normal and fast) in five minute stages. They found that MAPRs for the activPAL and the two pedometers (DW200 and NL 2000) were less than 1%, 2% and 2% of actual step counts, respectively, for both treadmill and outdoors walking speeds. These devices were considered suitable for measuring physical activity levels in community-dwelling older adults under different conditions (free-living and treadmill).

The accuracy of the DW 200 has been investigated in healthy populations under laboratory conditions (Le Masurier and Tudor-locke 2003; Horvath, Taylor et al. 2007). There is consensus that pedometers are less accurate at low speed walking (Crouter, Schneider et al. 2003; Tudor-Locke, Sisson et al. 2006). Individuals with disability are likely to have slower walking speeds compared to healthy controls (Kenyon, McEvoy et al. 2013). Thus, choosing appropriate pedometers for these populations is necessary for measurement of physical activity among individuals with disability.The accuracy of the DW200 and DW401 pedometers was examined in a population of people with multiple sclerosis, with 23 ambulatory participants who did not require a walking aid (Motl, McAuley et al. 2005). Participants walked at five different speeds (41, 54, 67, 80, and 94 $m{\cdot}min^{-1}$) on a treadmill in 5 minute stages. Both pedometers were accurate at speeds of 67 $m{\cdot}min^{-1}$ and above, with no significant difference between the actual steps performed and steps recorded by pedometers. At the slowest speeds (41 $m{\cdot}min^{1}$ and 54 $m{\cdot}min^{-1}$) both pedometers underestimated the number of steps that were actually taken. However, normal walking speed is accepted as being faster than speeds of 41 $m{\cdot}min^{-1}$ and 54 $m{\cdot}min^{-1}$. It is also considered important to examine the effect of wearing the pedometer in different positions on the body and the normal rate of accuracy for the DW 200. A study conducted by Horvath et al. (2007) reported DW 200 accuracy in 20 subjects in five different positions of wear under laboratory and over-ground conditions at three different speeds as well as during stair ascent and descent. Each subject attached five pedometers at once, three around the waist and two on the thigh at the following positions: left mid-axillary (LMA), left anterior mid-thigh (LMT), umbilical (UMB), right anterior mid-thigh (RMT), and right mid-axillary (RMA). They concluded that LMT position is more accurate than other positions across all conditions: LMT position recorded 2.2% error during treadmill compared to 4.0% in the RMA position, while overall error was 1.1% and 3.7% for over-ground both RMT and RMA respectively. The error at the LMA during stair ascent and descent were significantly lower ($p \leq 0.01$) than at other positions.

3.6.4.3 Laboratory and free-living conditions

Examining the accuracy of the DW 200 under different conditions when compared with other brands and using accelerometers as the criterion standard were needed to ensure the accuracy of this device. In 2004 Le Masurier et al. (2004) conducted a study to evaluate the accuracy of three pedometers, including the DW 200 using an accelerometer as a criterion under treadmill walking conditions at five speeds (54, 67, 80, 94, and 107 $m{\cdot}min^{-1}$) in 5 minute stages and under free-living conditions for 24 hours. Twelve adults (20-55 years old) were divided into two weight categories (four normal weights and eight overweight). To determine the accuracy between pedometers, MAPR was calculated comparing pedometer steps and actual steps taken. The DW 200 when compared with the other pedometers (Omron HJ-105, and Sportline 330), measured MAPR most accurately at less than 2.5% for speeds of 67 $m \cdot min^{-1}$ and above, but recorded greater error in the slowest speed of 54 $m \cdot min^{-1}$ with no significant differences between DW200 steps and actual steps taken over all speeds. The DW200 recorded the lowest MAPR in free-living conditions compared to two other pedometers (Omron HJ-105, and Sportline 330): 12.8, 25.8, and 37.0% respectively. This study also provided additional evidence that the DW 200 is the most accurate pedometer of those tested under different conditions and is suitable for research studies. Another study by Feito and colleagues evaluated the step count accuracy of six electronic pedometers, including the DW200 and StepWatch 3 (WS) which were used as criterion devices, under laboratory and free-living conditions (Feito, Bassett et al. 2012). A total of 56 participants with different BMI walked 100 steps on a treadmill at five different speeds and for two consecutive days in free-living conditions. They indicated that BMI had no effect on step count accuracy during either walking condition. All devices recorded high accuracy (more than 97% of actual steps taken) at speeds 80 $m \cdot min^{-1}$ and above, while all devices recorded the lowest accuracy at the slowest speeds with the exception of the criterion device StepWatch 3 (WS).

3.7 **Summary**

Physical activity guidelines are established in the USA, and a number of other countries have also produced physical activity guidelines that have focused on improved health and reduction of risk for health disorders (Tremblay, Warburton et al. 2011; Australian Government 2014). National and international guidelines have recommended that every adult accumulate at least 150 minutes of moderate-to-vigorous intensity physical activity weekly, to get health benefits and reduc the cost of health care (World Health Organisation 2011). Physical activity plays an important role in the prevention or minimization of different chronic diseases including type 2 diabetes (Li, Zhang et al. 2008; Umpierre, Ribeiro et al. 2011), cancers (Anzuini, Battistella et al. 2011; Loprinzi, Cardinal et al. 2012), overweight and obesity (Milanovic, Pantelic et al. 2012), and different musculoskeletal disorders MSDs (Proper, Koning et al. 2003; Hendrick, Wake et al. 2010; McDonough, Tully et al. 2013). There are consistent results of physical activity obtained by objective and subjective measurements. For example, Craig and colleagues concluded that the IPAQ showed a Spearman’s correlation of p= 0.76

between reported and measured MET min per week in an adult population (Craig, Marshall et al. 2003). In terms of accuracy of pedometers, DW 200 pedometer accuracy is consistent across different conditions (laboratory, and free-living) under varying speeds, as well as for all population age groups. The researchers concluded that the DW 200 is an accurate and useful tool to assess ambulatory walking in a wide range of populations at speeds above 80 $m \cdot min^{-1}$ in free and controlled conditions. The importance of physical activity is clear for the general population, and it is also important to understand the use of a pedometer based intervention programmes to increase physical activity and improve health-related outcomes among workplace populations. Chapter four provides a comprehensive review regarding physical activity an intervention in the workplace with focusing on the effectiveness of a pedometer as intervention tools to increase physical activity levels within the workplace setting.

4 Chapter Four

Pedometer-based intervention within the workplace setting

4.1 Overview

The use of a pedometer is appropriate for monitoring step count, providing feedback on the amount of walking that can be used as a proxy for levels of physical activity. It is also considered to be effective as a motivational tool for promoting and increasing walking-based physical activity for all age groups (Siegel, Brackbill et al. 1995). The objective of this chapter is to summarise the literature that focuses on pedometer-based interventions for promoting physical activity and improving health-related outcomes among workplace populations. It is based on a narrative review of published research that has reviewed and evaluated the use of pedometers as a means to increase physical activity in workplace settings. The chapter begins with an overview of literature relating to physical activity interventions within the workplace. The use of pedometers as intervention tools to increase physical activity and other health outcomes in the workplace setting is then reviewed. The final section of the review focuses on the relationship between recorded levels of physical activity and the SF-36 questionnaire.

4.2 Physical activity intervention in the workplace setting

In recent years there has been an increasing interest in research regarding physical activity. A number of studies and systematic reviews in this area support the effectiveness of physical activity interventions for improving overall health (Bravata, Smith-Spangler et al. 2007; Chase 2011). Physical activity interventions are often recommended for prevention or to minimize risk and improve quality of life for various chronic diseases, including sedentary obesity, high blood pressure, and cardiovascular disease (Warburton, Nicol et al. 2006; Katzmarzyk and Lear 2012; Li and Siegrist 2012; Rossi, Dikareva et al. 2012). A number of studies also demonstrate the benefit of increased physical activity in reducing pain and improving health-related quality of life in workplace populations with MSDs (Proper, Koning et al. 2003; Burton, Balagué et al. 2005; Andersen, Christensen et al. 2010; Zebis, Andersen et al. 2011). A critical review by Proper and colleagues identified clear evidence for the benefit of worksite physical activity to manage MSD among employees (Proper, Koning et al. 2003). This review used a qualitative method and reported that 23% (6/26) of studies included in the review had a high methodological quality. Poor quality studies were due to poor study design, and lacked the use of objectively measured physical activity outcomes.

A systematic review of worksite physical activity interventions by Dugdill and colleagues provides some evidence that workplace-based walking interventions using pedometers, that included a counselling intervention, can increase daily step counts and positively impact upon physical activity behaviour (Dugdill, Brettle et al. 2008). In this review a number of included studies (14/33) had a high methodological quality, but the literature search was limited to studies published across Europe, Australia, New Zealand and Canada. A more recent systematic review investigated 58 studies using mixed strategy interventions such as counselling/support, promotional messages /information and physical activity/exercise interventions to promote physical activity.The results showed some evidence that workplace physical activity interventions can be efficacious in promoting physical activity when compared to a control group receiving no intervention (Malik, Blake et al. 2013). A general concern is that the included studies had several methodological shortcomings which may affect the level of evidence. Similarly, a systematic review by To Chen, found an improvement in physical activity levels, daily step count, and BMI. Interventions that used a pedometer that included activities at social and environmental levels more positively impacted upon physical activity behaviours than those without these characteristic (To, Chen et al. 2013). However, the majority of effective studies (69% ; 9/13) that used a pedometer intervention had reported a score of 3 or less out of 7 on the methodology scale.

While workplaces are a sedentary setting for many workers they have also been internationally recognized as an ideal setting for health promotion and physical activity strategies, as most workers spend about a third of their waking hours at the workplace (Dishman, Oldenburg et al. 1998; Christie, O'Halloran et al. 2010; Malik, Blake et al. 2013). Through the workplace it is possible to improve health status by increasing the level and capacity for a more physically active lifestyle, which may link to a reduction in occupational injuries and protect workers from accidents, reduce working hours lost as a result of absence due to illness or injury, reduce the costs of treatment, and claims for compensation (Odeen, Magnussen et al. 2013).

4.3 Pedometer as intervention strategy

Pedometers have been widely used in intervention studies that are based on step counts to increase the level of physical activity and improve health-related outcomes. The step counts used to motivate participants to increase physical activity with a target of achieving 10,000 steps per day has become a popular physical activity goal (Tudor-Locke and Bassett 2004). However, using a step count pedometer as a physical activity feedback tool is not enough to increase physical activity levels long-term; a combination approach with different strategies is advocated to increase adherence to physical activity and maintain and improve health status (Tudor-Locke and Lutes 2009). The use of pedometers with social cognitive theory such as self-efficacy, goal setting, feedback (Baker, Mutrie et al. 2008; Ashford, Edmunds et al. 2010; Houle, Doyon et al. 2012) and behavioural support materials about the health benefits of physical activity interventions (Haines, Davis et al. 2007; Freak-Poli, Wolfe et al. 2011) are considered an effective strategy to increase physical activity in the general population (Bravata, Smith-Spangler et al. 2007; Ashford, Edmunds et al. 2010) and in the workplace (Croteau 2004; Faghri, Omokaro et al. 2008). A systematic review examined the effectiveness of interventions aimed at promoting physical activity, and concluded that the strongest evidence exists for tailored interventions that focus at the level of individual needs within sedentary groups (Ogilvie, Foster et al. 2007). Thus the evidence suggests that the use of pedometers combined with individual goal setting may be the most effective strategy to promote walking and increase physical activity.

4.4 Field studies using a pedometer

There are clear links between increased physical activity and improvements in a number of health conditions. While the costs of managing chronic lifestyle diseases provide a classically high burden on an interventionist health care system, pedometer-based walking interventions are a potential alternative and/or complementary inexpensive strategy to increase the levels of physical activity in order to prevent and manage this chronic disease burden. Bravata and colleagues reported in their systematic review of 26 studies (8 RCTs and 18 observational studies) that used pedometers to increase physical activity and improve health outcomes in adult populations, that pedometer users significantly increased their physical activity by an overall 26.9 % over baseline, with increases of 2491 steps per day ($p<0.0010$) and 2183 steps per day ($p<0.0001$) in RCTs and observational studies respectively. Health outcomes improved showing significantly decreased BMI by 0.38 units ($p=0.03$), and systolic blood pressure by 3.8 mm Hg ($p<0.001$), with these improvements showing greater associations with participants having goals such as 10,000 steps per day ($p=0.001$) set at baseline (Bravata, Smith-Spangler et al. 2007). Results from the meta-analysis provided evidence for the effectiveness of pedometers to increase physical activity over all ages. Research that used different goal setting strategies such as 10,000 step goal setting, had a high effect size (ES= 0.84, 95%CI=0.43, 1.24) compared to the use of pedometer alone, while the effect of length of intervention was reported to range from moderate to high for studies that lasted < 8 weeks, from 8 to 15 weeks, and >15 week (ES= 0.68, 0.65, and 0.76, respectively) and with an overall increase of 2,000 steps over baseline intervention groups (Kang, Marshall et al. 2009). These results are consistent with another systematic review that examined the effect of pedometers to increase physical activity in a youth population, which reported that combining pedometer-based interventions with goal setting, or other behaviour strategies is more effective than pedometer alone particularly within low activity youth populations (Lubans, Plotnikoff et al. 2012).

A recent systematic review evaluated the effectiveness of workplace pedometer interventions for increasing physical activity and improving health-related outcomes in employed adults (Freak-Poli, Cumpston et al. 2013). The study included four cluster-randomised controlled trials, and found limited and low evidence for the effectiveness of pedometer-based workplace interventions for increasing physical activity. While one study reported significantly increased activity, the rest found no effect. The lack of effect in activity may be due to baseline differences between the intervention and control groups as well as different measures of physical activity used. High quality randomised controlled trials are thus needed to assess the effectiveness of pedometers in the workplace setting (Freak-Poli, Cumpston et al. 2013).

Using pedometers with different strategies has been recommended to increase the level of physical activity and weight loss in an overweight and obese population (Richardson, Newton et al. 2008). Pedometer-based walking intervention including goal setting and inactive behavioural change may be the optimal way to achieve and maintain weight loss by 1.27 kg (95% confidence interval, -1.85 to -0.70 kg) during a short term intervention (Richardson, Newton et al. 2008) and reduce the risk of chronic diseases that are associated with obesity and overweight. A recent publication has also demonstrated the effect of a pedometer-driven walking programme on relieving musculoskeletal symptoms (for both function and pain) in chronic LBP among adults aged 18 or over (McDonough, Tully et al. 2013) at least for the short-term.

4.5 Pedometers promoting physical activity levels in workplace

Pedometers have been used as motivational tools in various populations in order to increase the levels of physical activity and improve health-related outcomes in both the short and long term (Bravata, Smith-Spangler et al. 2007; Freak-Poli, Cumpston et al. 2013; To, Chen et al. 2013). Many individuals in the workplace spend long periods sitting during weekdays which contributes to the increased likelihood of becoming sedentary in their lifestyles (Miller and Brown 2004; Schofield, Badlands et al. 2005), and poor health behaviours which have been linked to an increase in the risk of chronic disease(Guthold, Ono et al. 2008) and decreased production capacity (Cohidon, Morisseau et al. 2009). Maintenance of physical ability and good health outcomes requires all sitting populations in the workplace to increase their activities and change lifestyle behaviours by various workplace interventions. Pedometer-based workplace interventions, including various combinations of strategies, may play a substantial role in increasing the level of physical activity in those populations. A recent systematic review conducted in a workplace setting reported that pedometer interventions with complementary activities at social and environmental levels were more likely to report successful outcomes than those that did not have these components (To, Chen et al. 2013).

The health benefits of a workplace physical activity intervention were advocated by Conn and colleagues; who found strong evidence for the effectiveness of workplace physical activity interventions, consisting of a combination of supervised exercise and motivational and educational strategies, on physical activity behaviour (ES=0.21); fitness (ES=0.57); lipids (ES=0.13); and anthropometric measures (ES=0.08) (Conn, Hafdahl et al. 2009). In contrast, a systematic review of pedometer-based workplace interventions for increasing physical activity summarized limited evidence for an effect of pedometer-based intervention on physical activity, and other health outcomes among workers (Freak-Poli, Cumpston et al. 2013). This review included only four studies that provide limited data which represents insufficient evidence to assess the effectiveness of pedometer interventions.

The focus of the current chapter has been on studies (Tables 7-9) that use pedometers as an intervention together with motivational tools to promote physical activity and improve health-related outcomes in workplace populations. The majority of studies used a pedometer-based workplace intervention as part of a multi-strategy and had various intervention lengths ranging from four weeks (Thomas and Williams 2006) to one year (Gemson, Commisso et al. 2008) with a median duration of 12 weeks' time period to improve health outcomes and increase physical activity behaviour. The total number of participants in these studies was 7506, ranging from 23 to 1239 participants. The majority of studies were conducted in the USA (9/23), Australia (5/23), and the UK (2/23) there was one study in each of Spain, Finland, Japan, Belgium, Canada, Brazil, and Sweden, as well as one further study conducted in seven different countries. The majority of studies (10/23) used pre and post-test design (Table 9), eight studies utilised a randomized controlled trial (RCT) design (Table 7), and five utilised quasi-experimental controlled designs (Table 8), published from 2004 to 2013. Nine studies recruited participants from universities and the remaining studies recruited employees from different sites. The majority of studies (57%; 13/23) had methodological shortcomings due to a lack of statistical intention-to-treat analysis or post hoc statistical analysis, and 78% (18/23) of studies failed to perform follow-up assessments post-intervention to test the long-term physical activity.

The delivery of a physical activity intervention format was multimodal for 23 studies consisting of a combination of behavioural strategies to motivate participants to reach 10,000 steps per day, such as face-to-face individual or group counselling, goal setting with regular contact or individual specific step goals, obstacle solving, social support, and use of the internet as well as posters and newsletter information to provide more information on the benefits of walking to maintain health. These programmes are consistent with recommendations from public health guidelines that advocate achieving 10,000 steps per day as a threshold (Tudor-Locke and Bassett 2004; Tudor-Locke, Craig et al. 2011). The majority of studies (63%; 15/24) reported that physical activity had significantly increased over baseline follow-up with results ranging from 10% up to 38%, except for one study (De Cocker, De Bourdeaudhuij et al. 2010) who reported a decrease in the levels of physical activity by step counts (p= 0. 071), with no significant difference in the amount of physical activity as recorded by the IPAQ in both groups (p= 0.264).

Tables 7-9 summarises important studies within workplace pedometer based interventions that provide a positive relationship between goal setting and/or other behaviour strategies and increased levels of physical activity in the short term. This is consistent with evidence from a meta-analysis and systematic review which suggests that combining a pedometer based intervention with behavioural strategies, particularly goal setting may be key motivational factors for significantly increased physical activity, and more effective than a pedometer alone in the general population (Bravata, Smith-Spangler et al. 2007; Kang, Marshall et al. 2009). In contrast, three studies reported non-significant positive effect on physical activity following the intervention. One study of these studies recruited unhealthy participants 30 to 59 year olds with high levels of attrition 35% (Maruyama, Kimura et al. 2010), while the other two studies recruited participants who were already active (Puig-Ribera, McKenna et al. 2008; De cocker, et al. 2010). However, most studies were quasi-experimental study designs either with two groups, which were allocated based on the workplace or one arm without a control group including participants who were already active. Effects were slightly larger in studies that recruited sedentary participants with low baseline step counts who could be more motivated to change their physical activity behaviour than higher level of activity participants. For example, Chan and colleagues conducted a pedometer-based workplace intervention in sedentary workers. The pedometer was used as a motivational tool and step feedback was provided with goal setting to change physical activity behaviour. Step count increased from baseline 7,029 steps per day to 10,480 steps per day. They concluded that intervention achieved the aims by changing behaviours in physical activity (Chan, Ryan et al. 2004). Warren and colleagues reported similar findings in overweight employees. The average steps increased on average by 38% from baseline5,839 steps per day to7,342 steps per day at the end of the intervention, with 93% of participants achieving their set goal. A personal social support, goal setting with 2000 steps as target and weekly email were applied to increase the number of steps and decrease sedentary behaviour (Warren, Maley et al. 2010).

In contrast, Faghri and colleagues undertook a 10 week pedometer-based intervention design based on the level of comfort on sedentary workers, to increase their walking speed and time spent walking during working hours. It contained weekly motivational email, logs of steps and minutes walked and teams of participants to motivate others. Wearing a pedometer increased physical activity from 4,185 steps, to 5,300 steps per day, a 27% increment ($p = 0.044$). Participants who reported more activity at baseline significantly increased step counts ($p<0.050$) compared to participants who were not active. On the other hand, while there was a significant reduction in systolic BP ($p = 0.011$) there was no significant difference in body weight after intervention (Faghri, Omokaro et al. 2008). A summary of these studies is detailed in Tables 7- 9.

4.6 Quality of life and physical activity

Health-related quality of life (HRQL) refers to the physical, psychological, and social domains of health, seen as distinct areas that are influenced by a person's experience, beliefs, expectations, and perceptions (Testa and Simonson 1996; Bize, Johnson et al. 2007). The relationship between physical activity and HRQL was reported by several reviews in a wide range of populations within different chronic conditions (Rejeski, Brawley et al. 1996; Proper, Koning et al. 2003; Thøgersen-Ntoumani, Fox et al. 2005; Bize and Plotnikoff 2009; Gillison, Skevington et al. 2009; Kjaer 2010) and revealed that the HRQL benefits gained from physical activity interventions are greater in individuals who have more chronic diseases than healthier individuals.

A systematic review of 14 studies with different study designs concluded that there was a consistent positive association of higher levels of physical activity with higher scores of health-related quality of life among healthy adults (Bize, Johnson et al. 2007). The largest cross-sectional study included revealed a large improvement in HRQL scores for people meeting the recommended activity from public health guidelines compared to sedentary groups. A further systematic review (Kjaer 2010) also found a positive association between physical activity and a variety of health-related quality of life measures in general populations. These findings are consistent with a recent systematic review of 13 studies with randomized controlled and controlled trials that investigated the effects of walking with poles (WP) on both physical and psychosocial health (quality of life) and showed consistent positive associations between WP and HRQL in adults with and without clinical conditions (Fritschi, Brown et al. 2012). The demonstration of a positive association between physical activity level and HRQL could provide healthy adults with motivation to become more physically active, more so than a more distant perspective of decreasing the risk of chronic diseases, particularly where there is a general tendency for individuals to underestimate their health-related risks. However, the majority of studies included in the Fritschi and colleagues review performed WP programmes for two to three times weekly with moderate intensity for eight weeks or longer.

Within the workplace setting there are few studies that have investigated the relationship between increased levels of activity and improved health-related quality of life. A very recent publication conducted at a workplace evaluated use of a pedometer to increase physical activity levels and improve HRQL over four months. Participation in the pedometer programme was associated with an improvement of the overall composition of HRQL with an increase of 1.5 mental component summary scores (MCS) units (95% CI: 0.76, –2.09) (Harding, Freak-Poli et al. 2013). The authors suggest that participants with greater increases in physical activity are more likely to improve in HRQL. Another study (Puig-Ribera, McKenna et al. 2008) evaluated the association between increased step count and HRQL changes. Overall, this study reported no significant group differences in step counts or HRQL during the programme. However, sedentary sub-group showed a significant increase in step counts ($p<0.010$) with greater changes in HRQL relative to active participants. Thus, it appears that increasing the level of physical activity particularly within sedentary workers is an effective way of improving health-related quality of life in this population.

4.6.1 Validity and reliability of the Short Form 36 Health Survey

The Short Form (SF-36) questionnaire is commonly used for measuring health-related quality of life (HRQL) among people with different health conditions (Edgar, Dawson et al. 2010; Papaioannou, Brazier et al. 2011) and the general population(Hemingway, Stafford et al. 1997; Frieling, Davis et al. 2013; Lera, Fuentes-García et al. 2013; Sinha, Van Den Heuvel et al. 2013). The SF-36 questionnaire is self-administered, and provides a generic health status that measures HRQL with eight sub-scales, each examining a different dimension of health. These include physical functioning, physical role, bodily pain, general health, vitality, social functioning, emotional role, and mental health (Ware Jr and Sherbourne 1992). The eight scales can be aggregated into two independent summary measures: physical component summary (PCS) and mental component summary (MCS). Scores for each variable are summed and transformed into a Likert scale ranging from 0 to 100, with higher scores reflecting the better health status and fewer role limitations (Jenkinson, Coulter et al. 1993). Scores can be calculated for each domain or by PCS and MCS scores.

The SF-36 was first developed and tested for the Medical Outcomes Study (MOS), a 2-year study of chronic medical conditions (Ware Jr and Sherbourne 1992). It has been shown to have very good psychometric properties, with high internal consistency and test-retest reliability values in various studies with a range of ages and health conditions (McHorney, Ware Jr et al. 1992; Ware Jr and Sherbourne 1992; McHorney, Ware Jr et al. 1994; Laosanguanek, Wiroteurairuang et al. 2011; Zhang, Bo et al. 2012; Lera, Fuentes-García et al. 2013; Sinha, Van Den Heuvel et al. 2013). It was developed for persons aged over 14 years and can be administered by self-completion, telephone, or by a trained interviewer. The reliability and validity of the 36-Item Short Form Health Survey (SF-36) questionnaire were assessed by conducting a cross-sectional study (Gandek, Ware Jr et al. 1998) of the general population across 11 countries (n = 1483 to 9151). Across all countries, correlations between items and hypothesized scales were greater than 0.40 with internal consistency reliability of the eight SF-36 scales above 0.70 for all scales. Results showed that the SF-36 questionnaire with translations in the 11 countries demonstrated good reliability and validity, and that it can be used to measure QOL among the general population (Gandek, Ware Jr et al. 1998).

4.6.2 Validity and reliability of SF-36v2

In 1996, a new version of the questionnaire (SF-36v2) was introduced which included improvements in the instructions, the wording of some of the items, and the number of response options for two of the eight scales (Ware 2000).Several studies have investigated the properties of the SF-36v2 and confirmed the improved precision, reliability, and validity of the SF-36v2 over the original version worldwide (Thumboo, Wu et al. 2013).

The SF-36v2 was assessed for validity and reliability in 4,917 participants of a multi-ethnic urban Asian population in Singapore using both English and Chinese versions of this tool. Results showed that SF-36v2 in both languages is valid and reliable for assessing HRQL with item-scale correlations exceeding 0.4 for all items and Cronbach's alpha exceeding 0.70 for all scales except social functioning (Cronbach's alpha: 0.68). Known groups comparison validity showed that all respondents with chronic medical conditions generally reported lower SF-36v2 scores on both language SF-36v2 scales (Thumboo, Wu et al. 2013).

Studies on the reliability and validity of the SF-36v2 have been conducted on a number of independent population and patient samples in a variety of countries (Taft, Karlsson et al. 2004; Morfeld, Bullinger et al. 2005; Motamed, Ayatollahi et al. 2005; Lam, Lam et al. 2008; Ngo-Metzger, Sorkin et al. 2008; Stephens, Alpass et al. 2010; Laguardia, Campos et al. 2011; ten Klooster, Vonkeman et al. 2013; Stull, Wasiak et al. 2014). While design, methodologies and patient/population samples of these studies have been at considerable variance, the SF-36v2 questionnaire appears to be a consistently reliable and valid tool for the assessment of health-related quality of life in the general population and population with chronic conditions. The SF-36v2 is now one of the most well used measures of health and quality of life in survey and clinical research. Although the measure has its critics and limitations, an advantage of its widespread use is the ability to compare results internationally and within local populations.

4.7 **Summary**

The nature of work in meat processing industries has a multitude of different tasks with most workers performing specific tasks for long duration, often requiring sustained standing, repetitive movements, and awkward postures which can increase the risk of occupational injury among workers. These features likely contribute to MSDs being a commonly reported health problem that impacts on health-related quality of life, and decreases daily activities. The importance of physical activity is clear for prevention and management of various chronic diseases and improving quality of life in workplace populations**.** Pedometers have been widely used as a motivational strategy and intervention to promote physical activity levels, and improve health status. This review provides the theoretical framework, and rationale for pedometer-based interventions through the use of written health materials, goal setting and regular contact, which may deliver positive effects for increased habitual physical activity and health outcomes in the short-term.

Table 7: Randomized controlled trials (RCTs) that used pedometers as motivational tools to increase physical activity and improve health-related outcomes

Study	Objectives	Subject	Intervention and control description	Theoretical approach	Results
(Aittasalo, et al. 2012)	To examine whether a 6-month pedometer intervention can promote walking and reduce sitting time among office employees	241 workers from 20 worksites randomized into two groups Pedometer n=123 Control n=118 Setting Finland	Intervention group received pedometer intervention for 6 months including: - one hour meeting at the beginning providing information on the intervention, health benefits for walking and how to use a pedometer .- self-monitoring of physical activity. - monthly emails Control group: normal lifestyle After one year follow-up a 1-hour meeting was offered to provide feedback on pedometer and intervention	Goal setting by adding 2000 steps/week to reach 10000 steps/day	Weekly walking minutes increased by 87 min in the intervention group compared to control group increased by 31 min. Sitting time during working day decreased by 41 min in the intervention group compared to control group decreased by 34 min after 6 months
(Maruyama, et al. 2010)	To examine the effects of a four-month intervention programme on metabolic parameters (MetS) in office workers	101 workers aged between 30 to 59 years old with risk of MetS in Tokyo	Intervention group: n=52; design based on self-efficacy which consisted of a combination of nutrition and physical activity programme. Participants asked to plan and change their habitual food intake by increase intake of good foods (A) and decreasing bad foods (B), and change lifestyle by increasing the step counts over a four-month intervention. Control group: n=49; given pedometers for seven days during baseline and follow-up periods.	Website personal page created and monthly counseling as well as 10 min face to face advice	No significant different between groups in step counts (p=0.160), significant difference between groups in food intake (p=0.00). Significant differences between groups were found in body weight (p<0.050, BMI p<0.050, insulin p<0.050, and HOMA-IP p=0.00)
(Puig-Ribera, et al. 2008)	To evaluate the effect of 9 weeks of pedometer walking while working to improve HRQL and job performance in university employees	70 workers from Catalan university in Spain; with average age of 41 years old and classified from low to high activity at baseline	Participants allocated into two intervention groups and a control group. I) Walking routes intervention group (n=19) received instruction to walk at least 15 min brisk walking every work day with mappings and examples. II) Walking while working group (n= 25) received a pedometer and were instructed to walk at least 10,000 steps/day and received weekly email containing information about goal sitting, obstacle solution, problem solving, and strategies for increasing step counts. III). Control group (n=26) normal lifestyle	Social cognitive behaviour: goal setting by 500 steps/week, social support, obstacle solution	No significant group differences in changes in step counts, HRQL, or job performance after intervention, but a significant increase in step counts (p<0.010) among sedentary participants and a significant decrease in step counts (p<0.050) among active participants. Overall sedentary participants had improvements in HRQL, and job performance
(Gilson, et al. 2007)	To evaluate the effects of a 10-week pedometer intervention to increase physical activity and improve health outcomes in university employees	58 women (age 42±10 years) and 6 men (age 40±11 years) university employees in UK	Participants randomized into two intervention groups and control group Control (n=24): received normal lifestyle Walking routes (n=23): participants asked to complete at least 15 min continuous walking around campus every work day. Walking tasks (n=23): same as walking route group, plus accumulate step counts through the lectures, seminars, and office	Weekly emails for intervention groups	A significant intervention effect (p<0.002) was found for step counts. Steps decreased in the control group (−767 steps/day) and increased in walking routes (+926 steps/day) and walking in tasks (+997 steps/day) groups.
(Ribeiro, et al. 2014)	To evaluate the effects of a 3-month pedometer intervention to increase physical activity and reduce anthropometric parameters in physically	195 women aged 40 to 50 years, randomized into four intervention groups	Minimal treatment comparator (MTC; n=47): received 3 individual sessions once a month (15 min each), contained information about the importance of physical activity for health benefits and received a booklet on how to increase physical activity.	Counselling sessions behaviour	Pedometer groups (PedIC and PedGC) significantly increased the steps after 3 months (p<0.05, 512 and 1475 steps/day, respectively) compared to the MTC group (-597 steps/day, p<0.05).

	inactive university hospital employees in Brazil		Pedometer-based individual counselling group (PedIC; n=53) received similar to MTC group plus pedometer with goal setting to increase by 2000 steps per day over the study. Pedometer-based group counselling (PedGC; n=48): received 6 GC sessions 60 min per week and 2 GC sessions with 2 weeks interval. Participants provided information on benefits of improved physical activity, barriers overcome, pedometer self-monitoring, 2000 goal setting, and 10 min self-efficacy walk. Aerobic training (AT; n=47). Received 24 treadmill training (moderate intensity) sessions, 2 times per week; lasted 30 min for first month, 35 min (2 month), and 40 min (3 month).		Significant decrease in weight and waist circumstance within all groups after 3 months (p<0.05) with greatest reduction observed from AT group.
(Carr, et al. 2013)	To assess the efficacy of a multicomponent intervention for reducing sedentary time and improving cardio metabolic disease risk with overweight university employees in USA.	40 sedentary female, randomized into two groups. intervention group (N=23; 47.6+9.9 years) control group (N=17; 42.6+8.9 years	The intervention comprised three components: 1. Portable pedal machine with software to perform light-intensity activity. 2. Website access provided tips on reducing sedentary behaviours. 3. 12 weeks of pedometer with website access to log step count and receive weekly motivational emails. Control group: normal lifestyle	Social Cognitive Theory	There was a significant decrease in sedentary time (−58.7 min/day; 95% CI, −118.4 to 0.99, p<0.01) and waist circumference (p= 0.03). There were no significant differences observed in other health outcomes such as blood pressure, BMI, and weight.
(Thøgersen et al. 2013)	To examine the feasibility of a 16-week pedometer intervention for increasing step count across different seasons in university employees, UK	75 sedentary participants randomized into two intervention groups. Spring intervention group n=40 Winter group n= 35. Age ranged from 24 to 63 years	Both groups were asked to walk for 30 minutes on three weekday lunchtimes and for 30 minutes on two independent walks during the weekends. From 1 to 10 weeks both groups' walks were group-led. From 11 to 16 weeks participants were asked to self-organize their own walks. Participants received supportive text messages every working day. Participants also received a log booklet to record their steps and goal setting as well as a weekly step count chart to progress their goals.		A significant effect of time on steps per day was seen over the intervention period (F 15, 1095) = 8.48; p < .01; partial $\eta 2$ = .10).
(Dishman, et al. 2009)	To evaluate the effect of 12 weeks of move to improve intervention to increase physical activity in worker populations	1239 employees from 16 worksite in USA	Intervention group (n=849) received a pedometer and personal goal setting for wlking time and steps to reach ≥10000 steps/day and ≥150 min of the MVPA / week with a handbook containing tools to assist participants to achieve their goals; teams ranged from 5-20 members Control group (n=390) received monthly newsletters containing information on the health benefits of physical activity	Self-set goal sitting every 2 weeks based on theory-based behavior modification to increase steps count and min of MVPA	Significantly increased steps count, min MVPA and satisfaction (p<0.001, p<0.001, p<0.010 respectively). Significant association between change of goal setting and increased physical activity (p<0.001), and satisfaction (p<0.001). Significant linear change in steps count and goals (p<0.001) and satisfaction (p<0.001)

Table 8: Quasi-experimental design studies that used pedometers as motivational tools to increase physical activity and improve health-related outcomes

Study	Objectives	Subject	Intervention and control description	Theoretical approach	Results
(Warren, et al. 2010)	To assess a 10-week pedometer intervention to increase walking and avoid weight gain among adult women at rural Worksites.	188 women (57.7% overweight or obese) from 10 workplaces in New York State	Ten-week pedometer intervention programme combined social support from workplace leaders, and strategies to promote walking (walking groups, marked walking circuits, and posted walking maps) were applied under three level: individuals, interpersonal and workplace. Participants received weekly email to set their goal setting at 2000 steps above baseline, and asked them to record their steps by project website	Ecological frame-work intervention. Weekly 2000 step goals, social support Feedback on walking steps. Motivational messages to keep walking	Significant increase in step count by 38% (p=<0.010; 5,839 to 7,342 steps/day) at the end of intervention, and 53% of participants achieved their step count goal. Sedentary proportion significantly decreased (p=<0.0005) from 42% to 26% at the end of the intervention
(Soroush, et al. 2013)	To assess the effects of a six-month pedometer on changes in blood pressure (BP) and cardiorespiratory fitness (CRF).	355 participants from two universities, aged 20 to 65 years	Participants received a pedometer and a study instruction booklet with a goal of walking more than 10,000 steps per day and weekly email to support and encourage them to achieve goals.		There was a significant decrease over time in systolic BP and diastolic BP (*p*=0.001, 5.57 mmHg and *p*=0.001, 4.03 mmHg respectively). Step count decreased from 12,256 at baseline to 8,586 steps per day at 6 months.
(De Cocker, et al. 2010)	To evaluate the effects of a 20-week pedometer intervention on physical activity behavior	147 participants from two workplaces in Belgium	Participants in the intervention group (n= 68) received 12 emails containing information on health, how to increase physical activity, workplace steps competition, and staircase use promotion over the time of the intervention. Flyers and posters were used and contained information about the benefits of staircase use and 10000 steps and physical activity guidelines. Control group (n=79): normal lifestyle	Social ecological model, and social cognitive theory	There was a decrease in steps count in both groups (p=0.071) and this was significantly different between groups (p=0.004). No significant change in workday steps between groups (p=0.262); significant decrease in weekend steps (p=0.044) in both groups No significant changes in the amount of IPAQ in both group P=0.264
(Borg, et al. 2010)	To evaluate the effect of a 12-week pedometer intervention with 12 months follow-up on maintaining physical activity level	332 inactive participants in Australia workplace	Intervention group (n=165) received a step by step guidebook to record steps and daily activity over 12 weeks, and newsletters containing information about social support, solving barriers, and walking environment in order to maintain the physical activity level over the 12 month follow-up. Control group (n=167) received a guidebook to record steps and daily activity over 12 weeks	Follow-up newsletters were based on the relapse prevention model	A significant increase in total physical activity, MVPA, and minutes walking within groups (p=0.01), and significant difference between groups in MVPA (p=0.03), total physical activity (p=0.057); no significant difference between groups in walking minutes (p=0.82)
(Gemson, et al. 2008)	To evaluate change in blood pressure (BP) and BMI after one year of pedometer and education intervention in workers with BP	141 employees with BP from 7 workplaces in USA; aged between 45 to 48 years old	Control group (n=94) received usual health care such as monthly screenings, and educational information about physical activity and BP, and nutrition and BP. Intervention group (n=47) received same as control group and additional pedometers with information on 10.000 steps recommendation and posters containing information on benefits of physical activity and BP	Goal setting to reach 10.000 steps/day Educational materials Verbal communications	There were significant differences between groups in systolic BP (p=0. 040), diastolic BP (p<0.010), weight (p<0.010), BMI (p<0.010), and physical activity (p=0.110) after one-year intervention

Table 9: Pre- and post-test design studies that used pedometers as motivational tools to increase physical activity and improve health-related outcomes

Study	Objectives	Subject	Intervention and control description	Theoretical approach	Results
(Hess, et al. 2011)	To evaluate workplace intervention nutrition and pedometer to promote physical activity and improve healthy eating	399 workers from Liverpool Hospital in Australia; 92.8% were female and the average age was 39.1 years	Intervention group n=399 participants divided into three occupation groups (nurses and doctors, allied health, and other professionals) the intervention duration was 12 weeks and included: pedometer, healthy eating and food fast log book, water bottle and sandwich box. Participants were asked to wear a pedometer over 12 weeks to reach 10000 steps per day and record their steps by logbook, and also recorded their daily eating of fruit, water and breakfast in the healthy log. No control group	10000 steps goal setting, weekly email and message by payslip about walking benefits, and posters to use the stairs as well as website for 10000 steps/day	The majority of participants (77.6%) reported that the pedometer was very useful to promote and increase their physical activity. 16.8% of participants reached ≥ 150 min/week (p=0. 001) and 94.1% tried to reach goal setting of 10000 steps/week
(Freak-Poli, e et al. 2011)	To evaluate the effect of 4 months of a workplace pedometer intervention to improve waist circumference (WC) variables in sedentary occupations	539 employees from 10 workplace in Australia	The pedometer intervention was based on Global Corporate Challenge (GCC) targeting 10,000 steps/day over 125 days. Participants received weekly email to increase their steps as well as health information from the website that was designed for this study No control group available.	Weekly email and goal sitting 10000 steps /day Health information by website	There was a reduction of 1.6 cm in the WC within sedentary participants compared to active participants at baseline decreased by 1.2 cm after 4 months pedometer. While greatest improvement exist in participants with high risk of WC 2.9 cm, and diabetes T2 2.2 cm.
(Freak-Poli, et al. 2011)	To evaluate the impact of a four-month pedometer–based workplace intervention on cardiovascular and diabetes risk	762 participants from ten workplaces in Australia	One intervention group based on the GCC programme aimed to increase physical activity by using a pedometer to reach 10000 steps/day guidelines and intake fruit and vegetables Programme includes: wearing a pedometer for 125 days with goal setting of at least 10000 steps/day using weekly emails to encourage them to achieve their goals, as well as health information provided by the website	Weekly email and goal setting at least 10000 steps/day Health information by website and daily record of step counts (6.4 km bicycle ride = 10000 steps/day)	A significant increase in steps between weeks one and two P=0.004, and also between weeks one and twelve P=0.039, but no significant difference between weeks two and twelve P=0.895 Significantly increased the time spent in physical activity P=0.002 and total physical activity P=0.030
(Shaw, et al. 2007)	To evaluate the effect of three-month pedometer intervention to increase activity levels in the workplace	23 staff at Caulfield General Medical Centre (CGMC) in Melbourne with an average age of 40 years.	Hot steppers programme consisting of educational sessions about physical activity and health benefits and barriers and enablers to using pedometers, as well as a log book to record their steps and activities	Educational materials	A significantly increased in steps between weeks one and two P=0.004, and also between weeks one an twelve P=0.039, but not significant between weeks two and twelve P=0.895 Significantly increased in the time spent in physical activity P=0.002 and total of physical activity P=0.030
(Faghri, et al. 2008)	To examine whether a 10-week pedometer intervention combined with a motivational programme can improve health outcomes in sedentary employees	206 sedentary employees from two workplace in USA; aged between 25 to 65 years old with high risk of chronic disease	Intervention programme designed based on level of comfort, where partiucipants increased their speed and time walking based on own comfort. Team walking, weekly motivational email, monthly newsletter, and website were used to increase step walking over 10 weeks	Online education by website internet	A significant increase in physical activity level P=0.044, step counts by 27% P<0.001 P=0.011, and also participants who reported more activity at baseline significantly increased step counts P<0.050 relative to participants who were not active.

					A significant reduction in systolic BP P=0.011 and no significant difference in body weight after intervention
(Haines, et al. 2007)	To evaluate the effect of 12-weeks of pedometer walking on BMI, BP, blood glucose BG, and cholesterol in college faculty and staff	120 participants with an average age of 44 years and BMI 30 kg/m^2 from USA setting	The pedometer walking programme consisted of 10-unit educational materials about physical activity and wellness by weekly email. Unit one contained information about physical activity and pedometer use, unit two contained a personal activity programme (goal setting 10% increase). The rest of the units included information about nutrition, and topics regarding wellness and physical activity, as well as feedback from pedometer.	Goal setting to reach at least 10.000 steps/day by increase 10% over baseline Educational materials by email	There was an increase in steps by 27% at the end of programme, and decrease in BMI from 29.06 to 28.76 P=0.024, blood cholesterol from 184.68 to 178.81 P=0.090, and BG P=0.060
(Thomas and Williams 2006)	To evaluate the effect of a four-week pedometer workplace walking programme to increase daily activity levels	927 participants aged from 18 to over 50 years old classified 66% active 29.5% insufficient and 4.5% inactive. USA setting	Four-week Ten Grand Steps programme: information session about the importance of physical activity for health benefits and 10.000 steps recommendations, goal setting. At the first week participants were asked to maintain the same habit to record their usual activity and set their goals to reach at least 10.000 steps/day; weekly email to support and encourage them to achieve goals.	Weekly email with information and goal setting reminder as well as an information session	There was an increase of an average of 873 steps/day 10% by the end of the programme and an increase in the average number of days that participants reached the target 10.000 steps from 2.2 to 2.8 /week (25%). The greatest increases 53% were from low active while insufficient activity increased 18%
(Chan, et al. 2004)	To evaluate the effects of a 12-week pedometer intervention to improve health outcomes in sedentary workers	106 workers from five workplaces with an average age of 43±9 years and the average of BMI 29.5±6.2 kg/m^2. Canada setting	The intervention programme consisted of two phases: 4 weeks adoption and 8 weeks adherence. In the first phase participants received 6 hours of training addressing the benefit of activity, goal setting, overcoming obstacles, and self-monitoring strategies, and were given 30-60 min each week during lunch time to walk. In addition, an internet website was designed to record their steps and weekly meetings. Phase two from weeks 5-12: participants received limited contact by email and continued their self-monitoring and goal setting as usual.	This programme design was based on the First Step Programme	There was an increase in the average number of steps /day by 10.480± 3.224 steps and a negative correlation between total steps and steps at baseline P<0.0001 but no significant correlation between baseline BMI and step increase P=0.4850. Significant decreases P< 0.050 in body weight, BMI, waist girth, and heart rate, while no significant changes in BP
(Gilson, et al. 2013)	To assess the effect of a six week pedometer programme on increasing step count among university employees	390 low active employees within 7 universities around the world	Intervention consisted of three phases: 1. For the first two weeks participants were asked to increase their steps by 1000 steps above their baseline 2. Weeks 3 and 4: increase 2000 steps above baseline 3. Last two weeks: increase 3000 steps above baseline. .	Weekly emails included tips on how to increase the level of physical activity. A website also offered to provide additional health information and log daily steps and feedback	Significant increase in step count from baseline to post-intervention (1477 daily steps; p=0.001). The greatest increases were from inactive sub-group (1837 daily steps) while low active subgroup (1464 daily steps) and somewhat active subgroup demonstrated the lowest increments (929 daily steps).
(Harding, i et al. 2013)	To assess whether a 4 month pedometer intervention can improve HRQL in workplace populations.	487 sedentary employees from different workplaces, with a mean age of 41 ± 10	One group received The Global Corporate Challenge (GCC) programme, consisting of monthly motivational emails about health benefits and step counts, and access to the website to record their steps and receive information on health benefits. During the 4 months participants were asked to walk in teams of 7 participants to achieve 10,000 steps as the target.	The Global Corporate Challenge (GCC) programme	Significant increase in MCS P=.001 and no significant difference in PCS P=0.13 over the intervention. No significant changes in the amount of self-reported physical activity P=0.19, but significant changes in self-reported physical activity within low active participants at baseline P= 0.04

5 Chapter Five

A systematic review of studies using pedometers as an intervention for musculoskeletal diseases.

5.1 Overview

Physical activity plays an important role in the prevention and management of a number of chronic conditions. The aim of this chapter is to investigate the evidence for effectiveness of pedometer-driven walking programmes to promote physical activity among patients with musculoskeletal disorders (MSDs). A comprehensive systematic review was performed using 11 electronic databases up to 20 February 2014. Keywords and MeSH terms included “musculoskeletal disorders”, “walking”, and “pedometer”. Randomized controlled trials, published in English, that examined the effects of a pedometer-based walking intervention to increase physical activity levels and improve physical function and pain in patients with musculoskeletal disorders were included.

5.2 Introduction:

The worldwide prevalence of musculoskeletal disorders (MSDs) is reflected in increasing costs (Brooks 2006; Murray, Abraham et al. 2013; Vos, Flaxman et al. 2013), occupational injury, and long term disability (Maul, Laubli et al. 2003; Osborne, Nikpour et al. 2007; Murray, Abraham et al. 2013; Vos, Flaxman et al. 2013). In particular, musculoskeletal pain constitutes an increasing problem in the ageing population (Okunribido, Wynn et al. 2011) and is an important factor underpinning functional limitations (Bremander and Bergman 2008; Walsh, Brooks et al. 2008; Collins, Janse van Rensburg et al. 2011). Consequently, musculoskeletal disorders have a large impact on activities at work and home (Walsh, Brooks et al. 2008; Collins, Janse van Rensburg et al. 2011), and place a considerable burden on the health care system (Osborne, Nikpour et al. 2007).

Physical activity plays an important role in the prevention and management of a number of chronic conditions (Warburton, Nicol et al. 2006; Warburton, Charlesworth et al. 2010; Reiner, Niermann et al. 2013), such as cardiovascular disease (Buchner 2009; Sattelmair, Pertman et al. 2009 ; Bassuk and Manson 2010), diabetes mellitus

(Gill and Cooper 2008), and obesity (Riebe, Blissmer et al. 2009), and has been shown to reduce premature mortality and improve quality of life (Warburton, Nicol et al. 2006) in the general population (Warburton, Nicol et al. 2006; Kjaer 2010). In recent years a number of studies have demonstrated the benefits of promoting an increase in Physical activity to reduce pain and improve quality of life in the adult population with MSDs (Hurwitz, Morgenstern et al. 2005 ; Benedetti, Berti et al. 2008; Andersen, Christensen et al. 2010), to reduce musculoskeletal impairment in the elderly (Benedetti, Berti et al. 2008), and reduce pain for those with low back pain (LBP) (Hendrick, Wake et al. 2010), neck pain, and shoulder pain (Bernaards, Ariens et al. 2007). Physical activity has also been shown to play a role in protecting against later hip fracture in an adult population (Hoidrup, Sorensen et al. 2001) and reducing the incidence of osteoporotic vertebral fractures in an elderly population (Bennell, Matthews et al. 2010). Results from a systematic review also support the effectiveness of Physical activity to treat and prevent a number of chronic disorders (Karmisholt and Gotzsche 2005). There are numerous modalities available for the management of MSDs, and considerable debate about the most effective interventions (Bremander and Bergman 2008); however, increasing Physical activity as part of the overall management approach is a key feature of a range of studies investigating the management of MSDs (Morken, Mageroy et al. 2007 ; Bremander and Bergman 2008).

Walking is deemed to be one of the most effective forms of Physical activity, with little risk of injury among low-activity populations (Siegel, Brackbill et al. 1995; Brownson, Housemann et al. 2000 ; National Institute of Clinical Excellence 2006); it has been used successfully as an intervention to reduce the burden of a number of chronic diseases including hypertension (Lee, Watson et al. 2010), cardiovascular risk (Tully, Cupples et al. 2005), obesity (Tessier, Riesco et al. 2010), and osteoarthritis (OA) (Roddy, Zhang et al. 2005). Currently, there are a number of studies that support the use of walking-based interventions to encourage people with a range of MSDs (Roddy, Zhang et al. 2005; Hendrick, Wake et al. 2010) to assume a physically more active role in their management.

Pedometers have been commonly employed to provide a measurement of walking undertaken as part of a physical activity programme, to provide patient feedback, and as a motivational instrument within intervention programmes designed to increase activity and improve the quality of life, across a range of clinical conditions including: chronic obstructive pulmonary disease (COPD) (Hospes, Bossenbroek et al. 2009), diabetes (Furber, Monger et al. 2008; Diedrich, Munroe et al. 2010), inactive overweight and obese older people (Sugden, Sniehotta et al. 2008; Pal, Cheng et al. 2009), and healthy adults (Marshall, Levy et al. 2009; Tudor-Locke and Lutes 2009). In addition, a number of studies describe a variety of pedometer-driven walking research protocols for adults with low back pain (Krein, Metreger et al. 2010; McDonough, Tully et al. 2010) designed to assess the effects on pain-related disability and functional interference.

A systematic review on the effect of aerobic walking or strengthening exercises for OA of knee found walking to be effective in decreasing pain and improving function in this population (Roddy, Zhang et al. 2005). Hendrick and colleagues similarly presented moderate evidence for walking interventions playing a role in decreasing pain levels in patients with acute and chronic LBP (CLBP) (Hendrick, Wake et al. 2010). However, there is little standardization between protocols as to the most effective pedometer-driven walking programmes for MSDs, and therefore it is difficult to evaluate the relative effectiveness of one programme over another within this population. As there has been no systematic review focusing on the effectiveness of pedometer-driven walking programmes as part of the management of adults with MSDs, the primary purpose of this systematic review was to investigate the evidence for pedometer-driven walking programmes as an intervention in promoting Physical activity and improving health-related outcomes when compared to no intervention, or a different type of intervention, among adults with MSDs.

Research question: Does using a pedometer-driven walking programme increase physical activity, and/or improve health in patients with MSD?

5.3 Methods

5.3.1 Search strategy

A systematic search of the literature was carried out using the following electronic databases: MEDLINE, CINAHL, Embase, Cochrane Library, PubMed, Scopus, PEDro, Web of knowledge, Sport Discus, AMED, and Science Direct. All databases were searched from their inception to 20 February 2014. Keywords and MeSH terms used in the search strategy were: "musculoskeletal diseases" OR "osteoarthritis" OR "back pain" OR "spinal pain" OR "knee pain" OR "ankle pain "OR "hip pain " OR "shoulder pain" OR "lower extremity” OR "pelvic pain" AND “walking” OR "physical activity" OR "aerobic exercise" AND “pedometers” OR “step counter” (Table 10). In addition, the reference lists of all included articles were also searched for further relevant studies that may not have been identified by the search strategy described above.

Table 10: Search strategy used to identify the articles

Term category	Words
MeSH terms	“Musculoskeletal diseases” OR “back pain" OR "spinal pain" OR "knee pain" OR "ankle pain "OR "hip pain" OR "shoulder pain" OR “osteoarthritis” OR "lower extremity” OR "pelvic pain" and “Walking”
Keyword	“Physical activity”, "aerobic exercise", “Pedometers” and “step counter”

5.3.2 Study selection

The review was conducted in three steps. Firstly, the first reviewer Suliman Mansi (SM) title-screened all articles for potential inclusion. The abstracts of those studies were then independently reviewed by two reviewers (SM and Paul Hendrick, PH) and consensus sought for acceptance for review of the full-text article. In the final step, the references of all full-text articles were searched for additional articles.

5.3.3 Inclusion and exclusion criteria

Studies were included if they met the following criteria:

(1) Randomized controlled trials (RCT) and controlled trials without randomization published in the English language.

(2) Restricted to adults aged 18 years and over with an MSD.

(3) Used pedometer-driven walking as an intervention to increase physical activity, and/or improve health outcomes (physical function, and pain).

(4) Studies investigating mixed disorder presentations (MSD as a primary and another disorder) were also included. Studies that investigated measurement validity or reliability tests of a pedometer walking programme were excluded.

5.3.4 Extraction of data

Data extraction for all included studies was performed by the first author (SM) and cross-checked for consensus by a second author (PH). Data related to author, year of publication, study design, objectives, sample and participants, components of pedometer intervention, mean steps per day, and outcomes were extracted and tabulated.

5.3.5 Quality assessment

The methodological quality of the studies included in this review was assessed using a criteria list that has been used in previous reviews (Proper, Staal et al. 2002; van Sluijs, van Poppel et al. 2004). The criteria list (Table 11) includes four domain measurements to assess the quality of the study design (A and B); research population (C and D); quality of measurements (E, F, G, and H); and quality of analysis (I and J). These criteria were applied, with two reviewers independently evaluating the methodological quality (SM and PH). The criteria answer format included positive (+), negative (-), or unclear (?). Possible scores ranged from 0 to 10; studies that scored ≤ 5 were deemed to be low quality, and ≥ 6 represented high quality. In addition,the methodological quality considered the study to be of high quality if more than 50% of the methodological criteria was scored positively. Otherwise, the study was considered to be of low quality. To determine the effectiveness of the interventions, a rating system comprising four levels of evidence was performed, based on a best-evidence synthesis (Slavin 1995) used previously for physical activity interventions (Singh, Uijtdewilligen et al. 2012; Geraedts, Zijlstra et al. 2013). The results were considered to be consistent if at least 75% of the studies involved reported statistical significance or were meaningful as already defined.

• Level 1, strong evidence: multiple RCTs of high quality with consistent positive results.

• Level 2, moderate evidence: one RCT of high quality and one or more relevant low quality RCTs. Consistent positive outcomes of the studies.

• Level 3, limited evidence: only one RCT of high quality or multiple low quality RCTs. Consistent positive outcomes of the studies.

• Level 4, no evidence: only one low quality RCT, negative or contradictory outcomes of the studies, or no relevant studies.

Table 11:Criteria list for the methodology quality assessments

Item	Description
A	**Randomization:** Is randomization described and adequately performed? Positive if a random assignment to the research groups was performed and had been described explicitly.
B	**Control condition:** Is there an adequate control condition? Positive if the control group is from that same setting as the intervention group and (1) an alternative treatment was given, (2) if there was a comparable condition that controlled for a part of the intervention, (3) if usual care was given, or (4) if nothing was done.
C	**Research groups comparable at commencement:** Positive if the comparability of the research groups was statistically tested before the start of the intervention and the tests showed that the intervention group and control group did not differ with respect to age and at least one of the relevant outcome measures. In case the groups did differ, positive if this difference was.
D	**Dropout described and acceptable:** Positive if (selective) dropout was described and when dropout was <20% at short-term follow-up (6 months or less) and <30% at long-term follow-up (longer than 6 months).
E	**Was the person conducting the measurements blind for group assignment (or was an attempt made at baseline?):** positive if the measurements were conducted by a person blind for group assignment or if data collection was done with questionnaires that the respondent could fill out, in a situation not influenced by the researcher.
F	**Respondent blind for group assignment:** Positive if the respondent had (or could have had) no knowledge on the results of the group assignment.
G	**Timing of measurements is comparable for the different research groups:** Positive if the measurements were conducted at comparable moments for both the control group and the intervention group.
H	**Is the length of the follow-up described and acceptable?** Positive if a follow-up of 6 months or longer was described.
I	**Intention to treat-analysis:** Positive if all initially included and group-assigned participants are mentioned and analyzed in the original groups.
J	**Control for potential confounders:** Positive if the analysis controlled for potential confounders.

5.4 Results

A total of 1996 articles were retrieved using the search strategy detailed in the methods section. Based on the title, 1848 articles were excluded: 323 as duplicate titles and 1525 did not meet inclusion criteria because they did not include a pedometer-based intervention. One hundred and forty-eight abstracts were then reviewed by the first author (SM). One hundred and eighteen of these abstracts were excluded because they did not meet inclusion criteria, again with the majority of these exclusions (111) being related to having no pedometer-based intervention present in the study. Full-text retrieval was conducted for the 30 remaining articles. Twenty-three of these manuscripts did not meet the inclusion criteria and were excluded due to the following reasons: Non-RCTs (2), protocol study (4), pedometer not part of intervention (7), and measurement validity/reliability (10). A total of seven articles met the full selection inclusion criteria (Fig 7). No further studies were identified from the manual search of the reference lists of included articles.

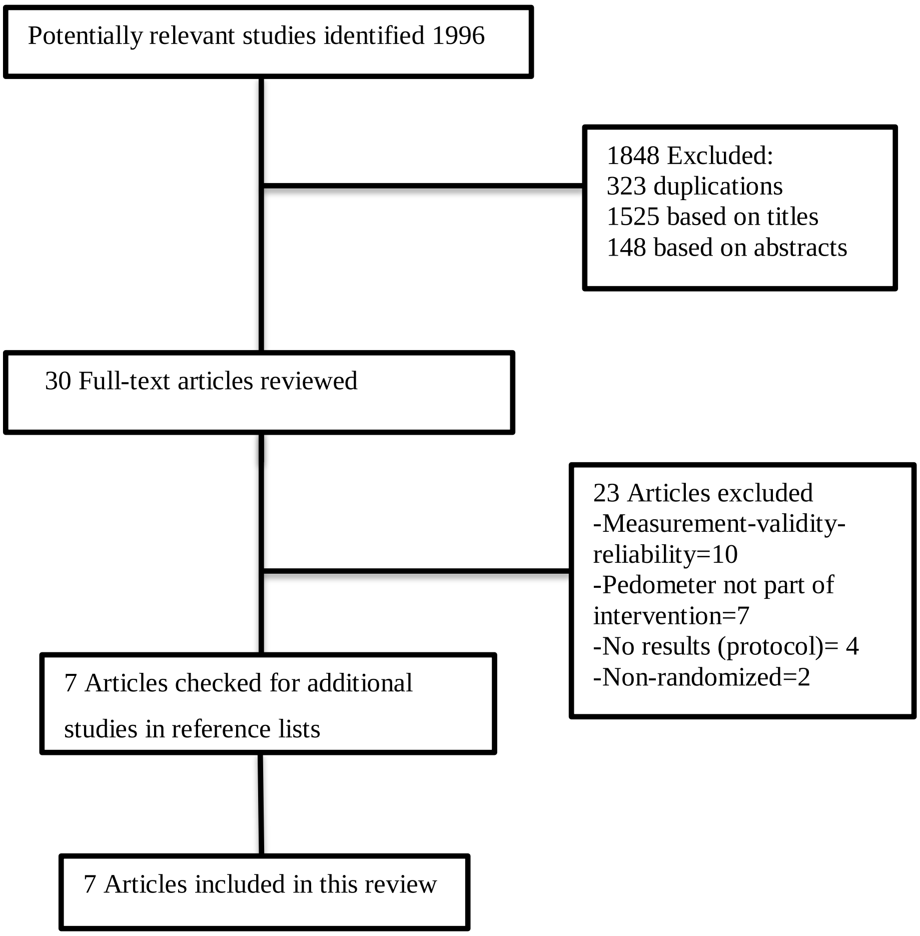

Figure 5: Progress through the stages of study selection

5.4.1 Study characteristics

All seven included studies were of a randomized controlled trial (RCT) design and ranged in date of publication from 1998 to 2013 (Toda, Toda et al. 1998; Talbot, Gaines et al. 2003; Fontaine and Haaz 2007; Ng, Heesch et al. 2010; Hiyama, Yamada et al. 2012; Krein, Kadri et al. 2013; McDonough, Tully et al. 2013). Three of the studies were conducted in the United States, (Talbot, Gaines et al. 2003; Fontaine and Haaz 2007; Krein, Kadri et al. 2013) while two studies were conducted in Japan (Toda, Toda et al. 1998; Hiyama, Yamada et al. 2012) one was Australian (Ng, Heesch et al.

2010) and another study was conducted in Ireland (McDonough, Tully et al. 2013). The total number of participants across the seven studies was 484, with an age range of 40 to 82 years. Five of the seven studies included both males and females (Talbot, Gaines et al. 2003; Fontaine and Haaz 2007; Ng, Heesch et al. 2010; Krein, Kadri et al. 2013; McDonough, Tully et al. 2013) while two studies (Toda, Toda et al. 1998; Hiyama, Yamada et al. 2012) recruited females. Sample size ranged from 34 to 229, with the greatest contribution of 229 participants coming from Krein et al 2013 (Krein, Kadri et al. 2013). The majority of included studies examined the effectiveness of a pedometer-driven walking programme to increase physical activity levels in adults with MSDs. A summary of these studies is provided below.

Talbot and colleagues compared the effectiveness of a pedometer-driven walking programme with goal-setting versus an education programme (no pedometer) by two registered nurses in 34 participants aged over 60 years, with osteoarthritis of the knee. Participants in both the walking intervention and control groups received a 12-hour education arthritis self-management programme including 1 hour of information on exercise for coping with arthritis. Participants in the intervention group also received a pedometer, step goals, feedback, and an education booklet. Outcome measurements were evaluated at baseline, week 12 and week 24 (Talbot, Gaines et al. 2003).

Ng et al (2010) compared the effectiveness of two different pedometer-driven walking programme interventions called 'Stepping Out' on osteoarthritis symptoms of the hip and knee in 36 patients aged between 42 and 73 years, over a 24-week period. The first group (A) received a pedometer walking programme three times per week plus glucosamine sulphate (GS) intake, and the second group (B) received a pedometer-driven walking programme undertaken five times per week plus GS intake. Both groups received GS intake alone for 6 weeks before the Stepping Out programme commenced. By the sixth week session, participants were asked to initially walk at least 1500 steps per day, and gradually increase their steps from 1500 to 3000 steps per day by the week 12 assessment. From the twelfth week, participants were asked to increase their walking to 6000 steps per day until the eighteenth week. Participants in group (B) received the same programme and procedures with the same goals, but were asked to walk five days per week (Table 12). Between week 18 and the 24 week follow-up, participants were instructed to continue with either the walking programme or to try another physical activity as an option. Results were reported at week 6, 12, 18, and the 24-week follow-up.

Table 12: Intervention design

0-6 weeks	7-12 weeks	13-18 weeks	19-24 weeks (Follow-up)
GS intake only	Walking up to 3000 steps per day plus GS	Walking up to 6000 steps per day plus GS	Any physical activity choice

GS: glucosamine supplements, PA: physical activity

Fontaine and Haaz (2007) examined the effects of a pedometer walking programme on health status, pain, and physical activity in low-active adults with fibromyalgia syndrome (FMS). Forty-eight participants aged 18 years or older diagnosed with FMS were randomized into one of two groups: a pedometer based intervention group or a control group. The pedometer based intervention group included a 90-minute cognitive-behavioural physical activity programme (which provided an overview of FMS, problem solving, goal setting, and self-monitoring) every two weeks for 12 weeks. At the first week, participants were asked to wear the pedometer during waking hours and to record daily step counts, while walking 10 minute per day five to seven days per week, and to gradually increase daily duration of walking by five minutes every week. The control group received a 90 min fibromyalgia education programme once a month over a three month period, including information on the symptoms, diagnosis, exercise and physical activity, and treatment for FMS, without wearing pedometers.

Toda et al (1998) examined the effects of a weight loss program for improving symptoms of OA in obese patients with knee OA. They investigated a number of variables in the weight control programme (including weight, total cholesterol, triglycerides, blood glucose, serum levels of insulin, and physical activity by pedometer) to determine if any of these factors were associated with symptomatic relief of knee OA symptoms. Both groups received non-steroidal anti-inflammatory drugs (NSAIDs) alone for 4 weeks before the study. The intervention group then received 0.5 mg Mazindol once per day plus NSAID medication twice a day, with 150 ml low calorie soup given at both breakfast and lunch for 6 weeks; in addition this group was instructed to wear a pedometer and to walk for 30 minutes each day for 6 weeks, during both work and leisure time. The control group received the same NSAIDs as the intervention group for 6 weeks, and a pedometer walking programme without any specific instructions. McDonough and colleagues examined the feasibility of a pedometer walking programme with education advice increasing physical activity in patients with CLBP (McDonough, Tully et al. 2013). The study randomized 57 patients to a pedometer intervention group (n = 40) or to a control group (n=17; education advice). All participants attended a one-hour session on education advice and completed a 10 minute self-efficacy walk at week one. Participants in the intervention group received a pedometer for 8 weeks, with individual step goals, feedback, regular contact, and education advice. Results were reported at baseline, week 9 and 6 month follow-up.

Krein et al (2013) examined the effect of a pedometer-based internet-mediated intervention on reducing CLBP at 6 and 12 months for 229 patients who were divided into an intervention group (n = 111) and a control group (n = 118). The intervention group received uploading pedometers and access to the intervention website which including goal setting, feedback, motivational messages, and social support following the Stepping Up to Health programme. The control group also received pedometers but without goals or feedback. Lastly, Hiyama et al (2012) randomized 40 patients with knee osteoarthritis to a walking group including pedometer (n = 20) or a control group (n = 20) for 4 weeks. All participants attended physical therapy once a week, and completed exercises for muscle strengthening and range of motion every day at home. The walking group received instructions to increase their steps to 3000 steps more than baseline value and record their steps every day. Outcome measurements were evaluated at the week before the intervention started and at week four of the intervention (See Table 13).

Table 13: Studies that used pedometers as an intervention for musculoskeletal diseases

Study	Objectives	Sample and Design	**Pedometer intervention**	Mean steps per day (baseline – follow-up) and pedometers	Result
RCT **Ng et al (2010) [50]**	To compare the effectiveness of two walking programmes in combination with GS on OA symptom and physical activity in patient with hip or knee OA	36 participants (age = 42-73), randomized into two intervention groups Group A n = 19 (walking 3 days/week) Group B n = 17 (walking 5 days/week) Programme lasted 12 weeks	From 0 to 6 weeks both groups received GS. Group A: From 7 to 12 weeks received GS + pedometer and walking up to 3000 steps/day, 3 days/week. From 13-18 weeks received GS + pedometer and walking up to 6000 steps/day, 3 days/week. Group B: same as group A but walking 5 days/week	3920 – 6683 (both groups) Pedometer: not mentioned	No differences between groups in steps/day ($p = 0.07$). Significant improvements in pain ($p = 0.001$) and physical function ($p = 0.001$) for both groups at 12 weeks
RCT **Talbot et al (2003) [51]**	To determine whether a pedometer programme with arthritis self-management would increase physical activity and muscle strength in subjects with OA of knee.	34 participants with knee OA (age = 60 and older), randomized into two groups. Pedometer group n = 17 Education group n = 17 Programme lasted 12 weeks	Both groups received 12 hours arthritis self-management education (UDE) over 12 weeks Pedometer group received instruction to increase their step count by 10% every 4 weeks from their baseline step count with feedback and exercise materials.	Education group: 4652 - 3972 Pedometer group: 3519-4337 Pedometer: New Lifesty-les Digi-walker SW-200, Yamax, Japan	Significant differences between groups in physical activity ($p = 0.04$), and muscle strength ($p = 0.04$) with no significant difference in pain ($p = 0.95$) at 12 weeks
RCT **Fontaine, & Haaz (2007) [49]**	To compare a pedometer programme vs. an education programme on health status and PA levels in adults with Fibromyalgia syndrome (FS).	48 adults (age = 48-52), randomized into two groups Pedometer group n = 22 Control group n = 26 Programme lasted 12 weeks	Pedometer group received 90min cognitive behavioural programme once every 2 weeks for 12 weeks. From week 1 participant were asked to increase walking by 10min every week to reach 30min by week 5. Control group: received 90min cognitive behavioural programme once a month for 12 weeks	Pedometer group: 2337-3970 Steps not recorded for control group Pedometer: Accusplit® Eagle Activity Pedometer	Significant increase in physical activity for intervention ($p = 0.001$). No significant differences between groups in pain ($p = 0.060$), fatigue ($p = 0.85$) or six-min walk ($p = 0.92$) at 12 weeks

RCT **Toda et al (1998) [52]**	To determine the variable most closely related to symptomatic relief of OA of knee in response to a weight control and walking programme.	40 women (mean age = 63.5), randomized into two groups Intervention group n = 22 Control group n=18 Programme lasted 6 weeks	Both groups received drugs (NSAID) for 4 weeks before study. Intervention group: received 0.5 mg Mazindol once per day plus the NSAID twice a day, and instructed to wear a pedometer to walk 30 min each day for 6 weeks Control group: received same as the intervention group but without any instruction or feedback on pedometer.	Intervention: N/R-7500 steps Control: N/R-7300 steps Pedometer: Seiko, Tokyo, Japan	No significant differences between groups in steps ($p = 0.86$) at 6 weeks. Significant correlation between steps and pain relief ($p = 0.003$)
RCT **McDonough et al (2013) [53]**	To examine the feasibility of an 8-week pedometer programme with education materials for CLBP patients	57 participants (age = 42-60), randomized into two groups Pedometer group n = 40 Control group n = 17 Programme lasted 8 weeks	Both groups received a single 1 hour education session. Pedometer group: in week 1, 10 min self-efficacy walk completed. Week 2, meeting to provide step target, between week 3 and 8 phoned weekly to discuss progress. This programme was based on 5As framework including 1. Ask/assess barriers to physical activity, 2. Advise to increase physical activity, 3. Change walking goals, 4. Address barriers with feedback, 5. Regular feedback.	Intervention group: 5563-8339 Control group: not reported Pedometer: Yamax, Digi walker CW-701, Japan	Participants in intervention increased their step count from baseline by 2776 (95% CI, 1996-3557), improvements in pain score (ODQ) by 8.2% (CI, -13-3.4) at 8 weeks
RCT **Krein et al (2013) [54]**	To determine whether a pedometer-based internet programme can reduce CLBP	229 participants (mean age = 51.9±12.8), randomized into two groups Intervention n = 111 Control n = 118 Programme lasted 12 months	Intervention group: received pedometer and access to a website which provided feedback, goal setting, motivational messages and social support Control group: received pedometer without access to intervention website	Baseline – 6 months: Intervention: 4492-5370 Control: 4322-4682 Pedometer: Omron HJ-720ITC	No significant differences between groups in steps at 6 and 12 months ($p = 0.12$, and $p = 0.08$ respectively). Significant difference between groups in RDQ scores ($p = 0.02$) at 6 month, and non-significant at 12 months ($p = 0.07$)
RCT **Hiyama et al (2012) [55]**	To examine whether a walking exercise can improves the dual-task performance in older adults with knee OA	40 participants, randomized into two groups. Walking group n = 20 (mean age = 71.9±5.2) Control group n = 20 (mean age = 73.8±5.7) Programme lasted 4 weeks	Both groups attended one session of physical therapy once a week, and also received ice therapy, exercises for range of motion and muscle strength at home every day. In addition, walking group received pedometer with instruction to increase their steps to 3000 steps more than their baseline	Walking group: 4453-7285 Control group: 4425-4207 Pedometer:KenzLifecoder EX, Suzuken Co, Ltd, Japan	Significant increase in physical activity for intervention ($p = 0.001$). Participants in intervention group significantly improved their functional disability and pain ($p < 0.001$, and $p < 0.001$ respectively)

5.4.2 Methodological quality assessment

Methodological quality scores are shown in the Table 14. There was 100% agreement between the two reviewers' independent evaluation scores. The quality scores achieved ranged from 3 to 10 with five studies scored ≥ 6 out of 10 as a high quality score (Talbot, Gaines et al. 2003; Ng, Heesch et al. 2010; Hiyama, Yamada et al. 2012; Krein, Kadri et al. 2013; McDonough, Tully et al. 2013), and two studies scored ≤ 5 out of 10 (Toda, Toda et al. 1998; Fontaine and Haaz 2007) as low quality scores. One study achieved a maximum quality score (Krein, Kadri et al. 2013), and five studies failed to score on the double blinding items (E and F); this may be due to the nature of the interventions.

Table 14: Methodological quality assessment scores for the included studies

Study	A	B	C	D	E	F	G	H	I	J	Total
Ng, Heesch et al (2010) [50]	+	+	+	+	-	-	+	+	+	?	7
Talbot et al (2003) [51]	+	+	+	+	-	?	+	-	+	-	6
McDonough et al (2013) [53]	+	+	+	+	-	?	+	+	+	+	8
Krein et al (2013) [54]	+	+	+	+	+	+	+	+	+	+	10
Hiyama et al (2012) [55]	+	+	+	+	+	+	+	-	-	+	8
Fontaine and Haaz (2007) [49]	?	+	+	-	?	?	+	-	?	?	3
Toda et al (1998) [52]	?	+	+	+	+	?	+	-	-	?	5

A: Randomization, B: Control condition, C: Research groups comparable at commencement, D: Dropout described and acceptable, E: Measurements blinded, F: Respondent blind for group assignment, G: Respondent blinded, H: Length of the follow-up, I: Intention to treat-analysis, J: Control for potential confounders

5.4.3 Pedometer Intervention

From the seven pedometer walking interventions reported among patients with MSDs, four interventions focused on improving knee osteoarthritis patients (Toda, Toda et al. 1998; Talbot, Gaines et al. 2003; Ng, Heesch et al. 2010; Hiyama, Yamada et al. 2012) while two interventions (Krein, Kadri et al. 2013; McDonough, Tully et al. 2013) targeted CLBP patients, and one intervention (Fontaine and Haaz 2007) focused on fibromyalgia patients. The duration of the interventions ranged from 4 weeks to 12 months, with several walking protocols including the Stepping Up to Health programme, (Ng, Heesch et al. 2010; Krein, Kadri et al. 2013) cognitive dual-tasks performance, (Hiyama, Yamada et al. 2012) the 5As model of behaviour change, (McDonough, Tully et al. 2013) active living every day, (Fontaine and Haaz 2007) and the walk + programme (Talbot, Gaines et al. 2003) as the framework for the interventions. However, the majority of those were based on Social Cognitive Theory (Bandura 2004) which involves using behavioural strategies such as goal setting, problem solving, self-efficacy, and social support to promote physical activity or to provide information on the benefits of walking to health or feedback and also to provide individual specific step goals.

In all interventions, participants were instructed to use pedometer driven walking at least three times per week. The drop-out rate between baseline and post-intervention varied between 7.5% and 29.0% except one study reported no dropouts (Hiyama, Yamada et al. 2012). Reasons for drop-out included death, increased pain, scheduling conflicts, and forgetting to attach the pedometer for several days. All intervention studies provided information on the amount of steps per day before and after the intervention except for Toda et al (1998). In addition, different pedometer models have been used (Digi-walker SW-200 (Talbot, Gaines et al. 2003), Yamax, Digi walker DW-701(McDonough, Tully et al. 2013), Seiko, Tokyo (Toda, Toda et al. 1998) Omron HJ-720ITC (Krein, Kadri et al. 2013); Kenz Lifecoder (Hiyama, Yamada et al. 2012); and Accusplit® Eagle Activity Pedometer (Fontaine and Haaz 2007) as motivational tool for increasing physical activity and as measurement tools across all seven studies; the details of models are shown in Table 13. However, the majority of included studies did not provide details regarding the validity and reliability of the pedometers or describe the instructions about how pedometers were used.

5.4.4 Effect of interventions on physical activity levels

All studies showed positive findings for using a pedometer to increase the level of physical activity over the intervention periods (Table 15). Five out of seven studies showed statistically significant improvements in step count in the intervention group relative to baseline (5/7: 71%; $p < 0.05$). Four of these studies had high methodological quality scores (Talbot, Gaines et al. 2003; Ng, Heesch et al. 2010; Hiyama, Yamada et al. 2012; McDonough, Tully et al. 2013) and one had a low quality score (Fontaine and Haaz 2007). However, the majority of studies used pedometers for goal-setting to increase the daily physical activity level. The pedometer goal-setting regime utilized by Talbot et al (2003) resulted in significantly increased ($p = 0.040$) step counts from baseline (from a mean 3519 steps per day to 4337 steps per day after 12 weeks) in the pedometer group compared to control, and no decreases in activity at the 24-week follow-up. Ng et al (2010) reported an increase in physical activity (number of steps per day from 3920 to 6683) over the 12 weeks in both pedometer-driven walking groups between week 6 and week 18. Fontaine and Haaz (2007) also found the pedometer-driven lifestyle physical activity group significantly increased physical activity levels ($p=0.001$) (daily steps increasing from 2337 to 3970) at 12 weeks post-intervention in the intervention group, with no step count data available for the control group.

McDonough et al (2013) showed an increase in daily steps taken of 2776 on average in the intervention group over 8 weeks, but no step count data was reported for the control group. A similar increase was reported by Hiyama et al (2012), who recorded a mean difference of 2832 steps per day in the intervention group after 4 weeks of intervention, which was significantly greater than in the control group ($p < 0.001$). In addition, Krien et al (2013) reported that daily step counts increased by an average of 878 steps per day within the intervention group compared to an average of 361 steps per day for the control group after 6 months of intervention, but this difference was not statistically significant.

Overall, results from across six studies reported that physical activity, assessed by walking, significantly increased by an average of 1950 steps per day (ranging from 818 to 2829 steps) over baseline assessment. However, it should be noted that this result is simply an average of the mean increases across six studies; individual results varied markedly.

Table 15: Pedometer data at baseline and after intervention

Study	Pedometer intervention			Control group			
	Baseline Mean(SD)	Post-test Mean(SD)	MD	Baseline Mean(SD)	Post-test Mean(SD)	MD	ES
Talbot et al (2003) [51]	3519 (2603)	4337 (2903)	818	4652 (2622)	3972 (2563)	-680	0.29
McDonough et al (2013) [53]	5563 (N/R)	8339 (N/R)	2776	(N/R)	(N/R)	(N/R)	0.59
Fontaine and Haaz (2007) [49]	2337 (427)	3970 (598)	1633	(N.P)	(N.P)	(N/R)	0.46
Toda et al (1998) [52]	(N/R)	7500 (N/R)	(N/R)	(N/R)	7300 (N/R)	(N/R)	0.62
Hiyama et al (2012) [55]	4453 (1734)	7285 (1638)	2829	4425 (1627)	4207 (1436)	-218	1.09
Ng et al (2010) [50]	3920 (2441)*	6683 (3403)	2763	(N.C)	(N.C)	(N/R)	0.38
Krein et al (2013) [54]	4492 (2749)	5370 (3180)	877	4322 (2285)	4682 (2925)	360	0.35

2N= two intervention groups *= for both intervention groups, N/R= not reported, N.C= no control group, N.P= pedometer not applied, SD= Standard Deviation, MD= Mean difference, ES= Effect size

5.4.5 Effect of interventions on health benefits

For secondary outcomes in this review, we found the majority of studies reported results on functional performance and pain scores. While there was a variety of measures used to assess disability and pain in these studies, the majority indicated an improvement in physical function, pain, or other health variables (fatigue, anxiety and depression) following the intervention (Talbot, Gaines et al. 2003; Fontaine and Haaz 2007; Ng, Heesch et al. 2010; Hiyama, Yamada et al. 2012; Krein, Kadri et al. 2013; McDonough, Tully et al. 2013). Four of these studies showed a statistically significant improvement in disability and pain scores (Talbot, Gaines et al. 2003; Ng, Heesch et al. 2010; Hiyama, Yamada et al. 2012; Krein, Kadri et al. 2013) in the intervention groups.

Krein et al (2013) found that a pedometer driven walking programme significantly decreased back pain-related disability as recorded by the Roland Morris Disability Questionnaire (RDQ) ($p = 0.02$, MD = 1.6, 95% CI, 0.3-2.8) compared with a control group at 6 months post-intervention. Similarly, Ng et al (2010) reported that the mean scores of the Western Ontario and McMaster University (WOMAC) and Osteoarthritis Index numeric rating scale (NRC) significantly improved ($p = 0.001$) in both groups between week 6 and the final follow-up points, with no significant difference reported between the groups in any outcome measure at any assessment point.

Hiyama et al (2012) used the Japanese Knee Osteoarthritis and Automaticity Index measures to assess participants' functional disability and pain. The study reported significant improvements in automaticity ($p < 0.001$) from baseline to post-intervention for the walking group. Functional performance, muscle strength, and pain were also measured by Talbot et.al (2003) who reported a significant increase in quadriceps femoris muscle strength ($p = 0.040$) and functional performance ($p < 0.050$) in the intervention group following the intervention, with no significant difference in pain scores. McDonough et al (2013) reported a greater reduction in levels of disability (Oswestry Disability Questionnaire; ODQ) by -5.5 points (95% CI, -8.8 to -2.2) for the intervention group compared with participants assigned to the control group (-1.0, 95% CI, -7.6 to -5.6). Toda et al (1998) found a significant correlation between the number of steps per day and increasing symptomatic relief of knee OA pain ($p = 0.003$, $r = -0.58$) and decreasing body fat ($p = 0.012$, $r = -0.62$).

5.5 Discussion

The primary aim of this review was to identify the effectiveness of pedometer-driven walking programmes in increasing levels of physical activity in patients with MSDs. Seven studies were identified which examined the effectiveness of pedometers to increase physical activity levels and improve physical function and pain in the short term. The majority of studies included in this review reported significant increases in physical activity ($p < 0.050$) following the intervention, with a mean positive change in physical activity of 1950 steps per day over the intervention period, and improved scores for pain and physical function after the intervention. This represents strong evidence (level 1) for the effectiveness of pedometer walking interventions for promoting physical activity levels in these patient populations. Evidence was appraised and synthesized based on the consistently positive results and high methodological quality of studies included in this review (Slavin 1995; van Sluijs, van Poppel et al. 2004).

5.5.1 Interventions and physical activity levels

It appears that pedometer based-walking interventions with a combination of behaviour strategies are effective to increase physical activity behaviour among MSD populations. The majority of studies included in this review used a number of strategies to maintain the increased levels of physical activity within the intervention programmes. These generally consisted of a range of goal setting strategies, and cognitive-behavioural approaches. For example, the study by Talbot et al (2003) reported an increase in the level of physical activity by 23% compared to a 16% decrease in steps in the control group. Such reported increases may be due to the targeted step goals employed, whereby participants were instructed to increase walking by 10% every 4 weeks above their baseline value. It may also be that giving feedback to patients on an individual basis and the provision of reading materials also supported the effectiveness of the intervention. These findings are consistent with previous studies targeting non-MSD conditions, including type 2 diabetes, acute coronary syndrome, and inactive populations (De Cocker, De Bourdeaudhuij et al. 2008; Sugden, Sniehotta et al. 2008; Hospes, Bossenbroek et al. 2009; De Greef, Deforche et al. 2010; Diedrich, Munroe et al. 2010; Houle, Doyon et al. 2012) that demonstrate positive effects for a range of pedometer-driven walking interventions combined with cognitive-behavioural strategies to increase physical activity levels and quality of life.

Data from other studies included in this review also report similar or higher increases in physical activity levels after the intervention (Fontaine and Haaz 2007; Ng, Heesch et al. 2010; Hiyama, Yamada et al. 2012; McDonough, Tully et al. 2013). This finding is reflective of evidence from previous studies which suggests that combining pedometer-driven walking programmes with goal setting (Sugden, Sniehotta et al. 2008; Diedrich, Munroe et al. 2010; Farhney, Kelley et al. 2010) or cognitive behavioural strategies (De

Cocker, De Bourdeaudhuij et al. 2008; De Greef, Deforche et al. 2010; Houle, Doyon et al. 2012) is more effective than pedometer-driven walking alone in adult outpatients. A case study that investigated a pedometer walking intervention in patients with OA (Farhney, Kelley et al. 2010) showed that incorporation of goal setting into the programme was effective in increasing physical activity levels. These findings are consistent with a recent meta-analysis of randomized controlled trials assessing promotion of physical activity within sedentary adults in primary care which reported the positive impact of physician counselling, written materials and advice sessions on increasing physical activity levels at 12 months (Orrow, Kinmonth et al. 2012)**.**

The daily increase in step count between baseline and following the intervention varied across included studies. The step-count increase ranged from 818 to 2829 steps per day over the intervention, with interventions ranging from 4 weeks to 12 months. Such variability may be a reflection of the range of conditions and populations, CLBP (Krein, Kadri et al. 2013; McDonough, Tully et al. 2013), hip and knee OA (Toda, Toda et al. 1998; Talbot, Gaines et al. 2003; Ng, Heesch et al. 2010; Hiyama, Yamada et al. 2012) different country settings, and accuracy of the pedometers used. For future study, attention must be taken regarding the validity of pedometers for disabled populations, and in particular factors which potentially impact on the measurement of the number of steps taken during the intervention, such as pedometers that are not accurate at low speed walking (Crouter, Schneider et al. 2003). An earlier systematic review exploring the validity of pedometers (Kenyon, McEvoy et al. 2013) reported that patients with disability are likely to have slower walking speeds compared to healthy controls. In addition, the reliability and validity of several pedometer models were examined in the literature (Schneider, Crouter et al. 2003; Schneider, Crouter et al. 2004) and they found the Yamax Digi-walker series pedometers (Yamax DW200 and 701, Kenz Lifecorder (KZ), New-Lifestyles NL-2000 (NL), and Omron (OM)) were the most suitable for measurement of physical activity in research studies; recording 1-3% error of actual steps taken at different walking speeds. Thus, choosing appropriate pedometers for these populations and determining the optimal pedometer placement is necessary to avoid methodological limitations.

The majority of studies included in this review used walking pedometer interventions in one trial arm that aimed at increasing physical activity levels in the short term, following a commonly applied physical activity recommendation (Warburton, Nicol et al. 2006; Haskell, Lee et al. 2007; Tudor-Locke, Craig et al. 2011) i.e. involving moderate intensity activities such as walking, three to five times per week, for 30 to 60 min per session. It is significant that patients with MSDs in these studies were encouraged to meet the minimum recommended levels of physical activity for health-related benefits (Morken, Mageroy et al. 2007 ; Jordan, Holden et al. 2010). The mean step count following the intervention ranged from 3970 to 8339 steps per day across the six studies, with an average of ≈5996 steps per day. The average increase of 1950 in step-counts represents a more than 32% increase above baseline (range 20% to 70%), and such increments are equivalent to approximately 20 minutes walking per day. Importantly, this increase in step count was sufficient to enable participants to meet the minimum recommended levels of physical activity (Tudor-Locke, Craig et al. 2011) of between 3500 to 5500 steps per day for people with physical disabilities (Tudor-Locke, Craig et al. 2011).

Although two studies (Fontaine and Haaz 2007; McDonough, Tully et al. 2013) reported significant increases in the number of steps after the intervention, they failed to report baseline and post-intervention step counts for the control group which precludes further evaluation and comparison of groups. A further study (Ng, Heesch et al. 2010) also reported an increase of 2763 steps over 12 weeks of the Stepping Out programme in both intervention groups, with no significant difference in the number of days per week spent walking between groups (3.07±0.82 and 3.93±1.09 mean days per week respectively). Thus, it appears that participation in walking either three days or four days per week were effective for increasing physical activity and reducing pain in this population. This result may reflect that the optimal walking period for patients with hip or knee OA is between two to four days per week in order to increase physical activity and improve health-related outcomes (Jones, Adams et al. 2006; Vignon, Valat et al. 2006; Loew, Brosseau et al. 2012). Equally, it may be difficult to ask such patients to walk more than three days per week, as most patients with hip or knee OA have inactive lifestyles and are three times more likely to have difficulty walking (Badley and Crotty 1995). However, walking three days per week may be advantageous for people with pain and disability, allowing them time for recovery during the rest times within the week.

People living with disability such as MSDs are usually classified as a low activity population (Kokkinos, Sheriff et al. 2011), which may be deleterious to their health and affect their ability to walk if the sedentary behaviour is sustained (Kokkinos, Sheriff et al. 2011). In this review we observed that all studies reported a low number of steps at baseline ranging from 2337 to 5563 steps per day, except one study with no assessment at baseline reported (Toda, Toda et al. 1998). This mean steps/day places these participants within the low active category (< 5000 steps per day) (Tudor-Locke, Craig et al. 2011). The increase in step count following the pedometer driven intervention in these studies is a reflection of an inactive population significantly improving their physical activity (Ogilvie, Foster et al. 2007) and potentially indicates that a cognitive-behavioural physical activity programme may be a key motivational factor for increasing physical activity behaviour. These findings suggest that pedometer based interventions in combination with behavioural strategies are effective in physical activity behaviour change (short-term) to motivate and track progress of their steps. This finding is consistent with a systematic review which found evidence to support the efficacy of behavioural interventions for promoting physical activity to sedentary adults in primary care (Orrow, Kinmonth et al. 2012)**.**

5.5.2 Interventions and health benefits

Previous research has shown that physical activity interventions improve overall health, with overall reduced general risk of premature mortality, (Warburton, Nicol et al. 2006) decreasing pain, and improving function with disability (Roddy, Zhang et al. 2005) across all groups and both sexes in the general population. Based on our data, significant improvements in disability and pain scores (Talbot, Gaines et al. 2003; Ng, Heesch et al. 2010; Hiyama, Yamada et al. 2012; Krein, Kadri et al. 2013) were reported in the intervention groups. Talbot et al (2003) reported a 21% increase in quadriceps femoris muscle strength in the intervention group compared to a 3.5% decrease in the control group. This result may in part be due to an increased step count in the intervention group and also potentially as a result of the 10% reduction in pain; however, there were no significant differences between the two groups for pain and physical function.

One study (Toda, Toda et al. 1998) reported that the number of steps per day was significantly correlated with symptomatic relief of knee OA pain and body fat loss after the intervention. This result may be due to the observed relationship between reductions in obesity levels and improved pain of knee OA (Lievense, Bierma-Zeinstra et al. 2002; Marshall, Bockstahler et al. 2009) and is also consistent with a meta-analysis of pedometer-based walking interventions that reported a weight loss of 1.27 kg (95% CI, 1.85 to 0.70 kg) through increasing physical activity in the short term, with more weight loss correlated with longer programmes (Richardson, Newton et al. 2008). Furthermore, a number of previous studies have shown a clear link between increased PA and weight reduction, with symptomatic relief of knee OA pain (Messier, Loeser et al. 2004; Van Gool, Penninx et al. 2005; Messier 2010).

Step count improvements were also correlated with a reduction in back pain related disability, symptoms of anxiety and depression, fatigue, and six-minute walk distance in the short term (Fontaine and Haaz 2007; Krein, Kadri et al. 2013; McDonough, Tully et al. 2013). These results are consistent with many similar walking intervention studies (Tudor-Locke, Williams et al. 2004; Roddy, Zhang et al. 2005; Andersen, Christensen et al. 2010; Farhney, Kelley et al. 2010; Jordan, Holden et al. 2010; Iwamoto, Sato et al. 2011) that demonstrated a positive effect of increased physical activity on pain and health-related outcomes in subjects with MSDs. Future studies are required to establish these findings within large powered clinical trials.

This review found strong evidence (level 1) for the effectiveness of pedometer walking interventions in increasing physical activity levels for patients with MSDs. Future research of high methodological quality with larger sample sizes is needed to investigate the effectiveness of pedometer-driven walking for improving physical activity and health-related outcomes in patients with MSDs. Such research is already underway: recently, two protocols have been published for controlled studies on patients with LBP using pedometer-driven walking programmes (Krein, Metreger et al. 2010; McDonough, Tully et al. 2010) in order to reduce pain-related disability and functional limitation.

5.5.3 Study limitations

This study has a number of limitations: variation in methodology, outcome measures, statistical methods and study subjects in the reviewed studies preclude a formal meta-analysis of the available data. We used four key elements of the design of the included studies to assess heterogeneity: the patients, interventions, outcomes and methods. Therefore, a narrative systematic review was conducted displaying information retrieved from the seven studies included in this review.

We also restricted our search to full–text articles in the English language, as well as the use of a limited keyword search and excluded doctoral theses and conference abstracts. This may have resulted in some relevant studies being missed. In addition, we calculated the mean number of steps as simply an average of the mean increase across six studies. Interpretation of the data and generalization of the findings should be considered; individual results varied markedly. Based on the data, the majority of studies included in this review also provided education programmes such as: information on the benefits of physical activity, arthritis self-management programme, LBP back book, and receiving medication to relieve their pain. These components may also have changed (increased) their physical activity habits leading to improvements in health outcomes.

The studies that we identified used a variety of different pedometer brands; however, the majority did not report sufficient information on the validity and reliability of pedometers used. The majority of studies included in this review mentioned the name of pedometers without providing any details on the validity and reliability of pedometer used. Several studies have been conducted to examine the validity and reliability of various pedometers under a variety of conditions to define the most accurate brand in adult populations. A study of adults (Schneider, Crouter et al. 2004) that compared thirteen models of pedometers under free-living conditions reported that the validity and reliability differed. We believe that the lack of information on the psychometric properties of the pedometers may have affected the report of step count levels, and hence the interpretation of physical activity.

5.5.4 Further research direction

Future research should explore the long-term effectiveness of pedometers in increasing physical activity levels in these populations. The majority of the studies included in our review included short term follow up, highlighting the necessity of longer term studies. Pedometer-driven walking interventions also need to be compared as single interventions, and ideally against current best treatments for patients with MSDs within an RCT design.

5.5.5 Conclusions

This review showed that the majority of studies reported a positive change in physical activity, providing strong evidence for the effectiveness of pedometer walking interventions in increasing physical activity levels for patients with MSDs. Improvements in physical function and pain scores were also noted in these study populations. It would appear that a combination of interventions using the pedometer, underpinned by cognitive-behavioural approaches to behaviour change, are likely to be more effective in increasing physical activity than the use of a singular intervention approach, which is consistent with recommendations from previous systematic reviews. Further research is required to support the role of pedometer walking interventions as a long term intervention for management of MSDs. The following Chapter investigates the feasibility of using pedometer-based intervention to increase physical activity levels and improve health-related quality of life among meat processing workers.

6 Chapter Six

Feasibility study to investigate the use of pedometer-driven walking to promote physical activity and improve health-related quality of life among meat processing workers

6.1 Background

From the results of chapters 2-5, the relationship between physical activity and improved health-related outcomes has been described. Moreover,the findings from the systematic review (Chapter 5) suggest that pedometer-based walking interventions with a combination of behaviour strategies are effective to increase physical activity behaviour and maximize health benefits in the short term. The current chapter outlines the methodology of a feasibility study using pedometer-based intervention to increase physical activity among meat processing workers.

Health benefits can be achieved by a variety of physical activity; walking is a practical, and considered to be an ideal form of physical activity to promote and maintain health status in the general population. For most it requires no additional physical skills, and is accessible to a large proportion of the population with little risk of injury (Tudor-Locke and Bassett 2004; National Institute of Clinical Excellence 2006). A systematic review (Ogilvie, Foster et al. 2007) examined the effectiveness of interventions aimed to promote walking, including 19 randomised controlled trials and 29 non-randomised controlled studies. The review concluded that the strongest evidence exists that tailored interventions that are focused at the level of individual needs among sedentary groups, such as pedometers with individual goal setting, are more effective to promote walking.

Walking with a pedometer as the intervention tool is becoming widely used in different health related domains to promote physical activity levels, and improve health status in a wide range of populations. Pedometers can supply valuable information on the number of steps and distance travelled, time spent in an activity, and also provide an estimate of energy expenditure (Lubans, Morgan et al. 2009). The majority are reliable and valid devices for increasing and measuring physical activity, particularly as part of a walking programme (McKay, Wright et al. 2009). In clinical studies pedometers have been widely used in the assessment and management of physical activity within a range of conditions including sedentary obesity (Sugden, Sniehotta et al. 2008; Pal, Cheng et al. 2009), diabetes (Diedrich, Munroe et al. 2010), and knee osteoporosis (Talbot, Gaines et al. 2003; Fontaine and Haaz 2007), with an aim to encourage increased habitual physical activity, and improve health-related quality of life.

6.2 **Aims**

The primary aim of this study is to evaluate the feasibility and acceptability of using a pedometer-based intervention programme to promote physical activity in meat processing workers. The specific study aims are:

Aim 1 To determine whether a 12-week pedometer-driven walking based intervention programme can improve health-related outcomes and increase average daily step counts in a sample of low physical activity adults employed in a meat processing workplace when compared to a control group receiving educational materials and advice alone.

Aim 2 To assess the effect of the intervention on blood pressure, body mass index, body fat percentage, waist circumference, and self-efficacy for exercise.

Aim 3 To assess the recruitment and adherence rates in a pedometer-driven walking programme group.

Aim 4 To estimate the effect sizes between group changes in health-related quality of life, physical activity levels, functional capacity, self-efficacy, and all secondary outcomes.

6.3 **Hypotheses**

A pedometer-driven walking programme will be a feasible and effective intervention to increase participants' daily physical activity levels and improve health-related outcomes.

6.4 Study design

A feasibility study with a randomized controlled trial (RCT) design collected data at three time points (baseline, 12 weeks (at conclusion of intervention), and 3 months post intervention). Ninety five participants registered interest, and all were assessed against the inclusion criteria by the principal investigator Suliman Mansi (SM). The first 60 participants who met the inclusion criteria were included in the study which comprised two arms (i) pedometer-driven walking (PW; n =30), (ii) control group receiving normal lifestyle advice (CG; n=30). This randomized clinical trial was reported according to the recommendations of the consort statement (Moher, Hopewell et al. 2012).

6.4.1 Ethical approval

The study design has been approved by the Otago Human Ethics Committee on the 25th of January, 2013 (Reference: 12/313; Appendix 1). In keeping with the University's partnership with Māori, the indigenous people of NZ, the project was submitted for consultation and received approval from the Ngāi Tahu Research Consultation Committee (Appendix 2). In addition, the study protocol was registered on the Australian New Zealand Clinical Trials Registry (ANZCTR): 12613000087752. Written informed consent was obtained before participants entered the study (Appendix 3).

6.4.2 Description and selection criteria of participants

A large, local meat processing plant in the South Island of New Zealand, employing 900 workers, agreed to participate in the study. Employee recruitment was conducted through advertisements (posters; Appendix 4) in different work-sites including the health clinic, plant administration, cafeterias, and all department notice-boards. Participants were eligible to participate if they were: working at the time of recruitment, male or female aged 18 to 65 years, had a sedentary lifestyle and/or low levels of physical activity (less than 7,499 steps per day); were able to walk continuously for at least 10 minutes; able to read and sign an informed consent form and questionnaires, and were willing to participate for the full study duration.

6.4.3 Screening

A total of 95 (38 male and 57 female) individuals volunteered to participate in the study. They were then screened by the principal investigator (SM) for eligibility for entry into the trial by wearing the pedometer (Yamax Digi-walker SW-200; Figure 6) for seven consecutive days during all waking hours for at least 10 hours a day. A convenience sample of 60 participants who met the inclusion criteria was recruited to participate in the trial to assess the feasibility of the intervention. Recruitment took place over a two month period between January and March 2013.

At the first contact participants were provided with details of the study requirements and an information sheet (Appendix 5) requiring informed consent prior to beginning the study. A self-report survey was then administered to each participant gathering demographic details such as age, sex, occupation, address, ethnicity, and hours of work in order to describe the study sample (Appendix 6). The ability of each participant to be physically able to participate in a walking programme was screened using the physical activity readiness questionnaire (PAR-Q) (Shephard 1988): if a participant answered yes to one or more questions on the PAR-Q, they were advised to consult with their healthcare provider and that physician consent was required prior to intervention participation (Appendix 7). All participants were healthy and none had any physical illnesses that might affect their normal daily routine according to their responses to PAR-Q.

Participants were instructed on how to wear and use the pedometer at the assigned location on their waist band above the lateral hip during all waking hours, except for periods immersed in water (bathing, swimming), during certain sporting activities (playing basketball or soccer, etc.), or in bed at night. They were instructed to reset the pedometer to zero at the beginning of each day, and remove it at the end of each day, record on a log sheet the date and the time the pedometer was attached and also removed, and the total number of steps displayed on the pedometer at the end of each day (Appendix 8). Participants completed a pedometer accuracy test at the beginning of the study (Tudor-Locke, Williams et al. 2002; Ryan, Grant et al. 2006; Sugden, Sniehotta et al. 2008). This test required each participant to walk along a straight 50 metre line while the principal researcher counted actual steps taken in order to ensure if the pedometer was recording steps accurately (acceptance criterion: ±2 steps).

Participants were instructed to continue with their normal physical activity patterns over seven consecutive days in order to obtain an indicator of their normal daily step count. After completion of these seven days' screening, participants were instructed to return the pedometer and log sheets to the principal investigator through personal contact and/or place the pedometer and log sheet at a designated site in their department office. The mean steps per day were calculated and data were included if a minimum of five days of pedometer was completed, based on the previous study acceptance protocol published by (Tudor-Locke, Burkett et al. 2005). Tudor-Locke and Bassett have previously classified pedometer-determined physical activity in adults by an average step count of less than 5,000 steps per day as a sedentary lifestyle, 5,000 to 7,499 steps per day as low activity, 7,500 to 9,999 steps per day as somewhat active, more than 10,000 steps per day as active and more than 12,500 steps per day as a highly active (Tudor-Locke and Bassett 2004). Using these data as a guide potential participants for the current study were excluded before baseline assessment if they accumulated an average of 7,500 or more steps per day.

6.4.4 Randomization

Sixty participants were eligible to participate in the study; however two participants dropped-out leaving 58 participants who were randomised into the two groups. Reason for discontinued participation was a wish to not participate and non-completion of the full study period. After successfully completing baseline assessment, randomization to one of the two groups was performed using sealed envelopes by an independent person not linked to the study. Participants were invited to choose an envelope from a basket containing envelopes that allocated 50% of the sample to the intervention and 50% to the control groups. Each envelope contained the group name for allocation, and the timetable of the study. The principal investigator and participants were not blinded to group allocation. A registered nurse, blinded to group allocation, performed assessment at baseline, 12 weeks (at the conclusion of the intervention), and 3 months post intervention. The staff members involved in the intervention and the assessor for final outcome measurements were blinded to group allocation. The flow of participants through the recruitment process and randomization is presented in Figure 8.

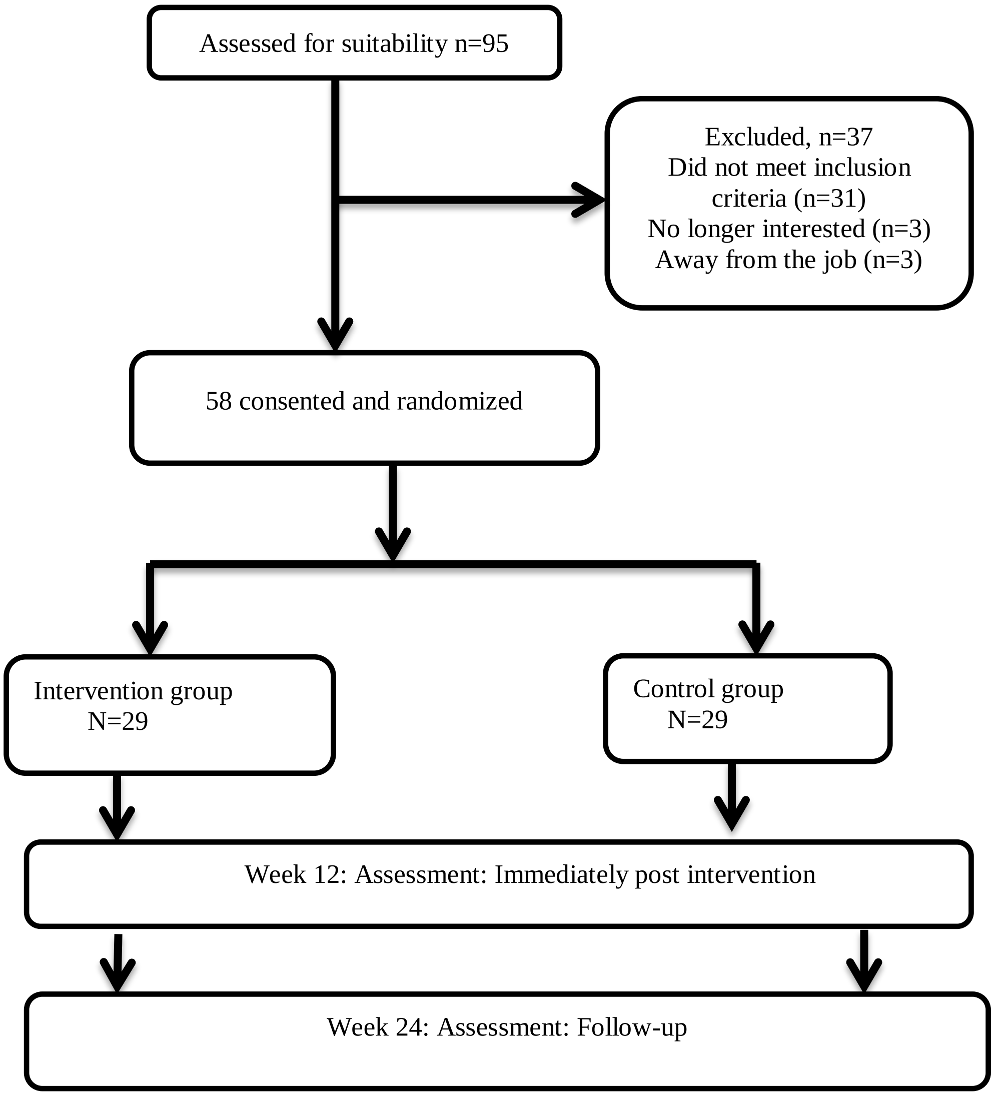

Figure 6: Flowchart detailing Study profile

6.5 Outcomes assessment and follow-up

Baseline measurements were taken before randomization. Outcome measurements were made at baseline, immediately after the 12 week pedometer-driven walking programme, and at the 3 month follow-up time points. After the post-intervention measurements all participants were advised to continue their normal physical activity levels and no other specific instructions on their activities were given to the participant during this time. A week before the 24 week follow-up point, reminder emails and telephone text messages were sent to invite all participants to return to the plant clinic and to complete all measurement requirements. In addition, a pre-paid return envelope containing pedometer and log sheets were sent to record their steps and return it as soon as possible after the 24 week time point to the principal investigator. Data for all outcome measures were securely stored and analysed once the trial was complete. The primary outcome measurements were quality of life, physical activity level, and functional capacity. Secondary outcome measures included blood pressure (BP), body mass index (BMI), body fat percentage (BF), waist circumference (WC), and self-efficacy.

The 58 participants wore the DW-200 on the waistband of their clothing for a period of seven days during the baseline period of the walking pedometer study, based on previous study protocols (Tudor-Locke, Burkett et al. 2005; Berlin, Storti et al. 2006; Clemes and Griffiths 2008; Kubota, Nagata et al. 2009) in order to establish baseline step-counts during normal daily activity. As all 58 participants accumulated an average baseline step count less than 7,500 steps per day; they were randomized to one of the two groups. In addition, during the seven days of pedometer assessment participants were asked to fill out three questionnaires (International Physical Activity Questionnaire Short Form (IPAQ-SF), The Short Form 36 version 2 (SF-36v_2), and Physical Activity Self-efficacy Scale) and each of the questionnaires was completed in the presence of the principal investigator at the plant clinic. Participants were also asked to have their blood pressure, body mass index, body fat percentage, waist circumference, height, and weight measured. Measurements were taken by the occupational health nurse employed in the plant clinic using the same instruments at each time point. Each participant's height and weight were used to calculate body mass index (BMI) by using the following formula: weight (kg) / (height (cm) 2). They were also asked to perform a six minute walk test with comfortable walking shoes for the test period. The time required for administering assessments was approximately 45-minute for each subject in each stage of study. After participation, participants were given a $20 gift card grocery voucher for their participation**.** Details of the assessments and questionnaires are as follows.

6.5.1 Health-related quality of life

All participants were asked to fill out the (SF-36v$_2$) questionnaire (Appendix 9) at three time points during the study period. Participants were informed about the SF-36 process and each question was explained at the baseline assessment if needed by principal investigator. The SF-36v$_2$ has been widely used to measure quality of life in general and specific populations (McHorney, Ware et al. 1993; Hasegawa, Suzukamo et al. 2008). It includes 36 questions and eight sub-scale domains of health-related quality of life, which are grouped into two components: a physical component score (PCS) and a mental component score (MCS). The physical component consists of physical functioning, and role limitations resulting from physical health problems, bodily pain, and general health problems. The mental component consists of vitality, social functioning, role limitations resulting from emotional problems, and general mental health (Ware 2000). The scores on all sub-scales range from 0 (worst score) to 100 (best score) (T-score transformation with mean, 50 ± 10 SD) (Ware 2000). The SF-36 questionnaire has been widely studied and reported to be a valid and reliable measure (McHorney, Ware Jr et al. 1992) of physical and mental health with good utility that can be completed in five to ten minutes (McHorney, Ware et al. 1993; Scott, Tobias et al. 1999).

6.5.2 Ambulatory activity levels

Objective change in physical activity level was measured using a pedometer. The Yamax Digi-walker DW-200 (Yamax, Tokyo, Japan) was used in this study. This model demonstrates acceptable reliability for research purposes in the adult population (Vincent and Sidman 2003; Schneider, Crouter et al. 2004). It was found to be the most accurate pedometer in counting steps, recording between 1-3% error within both free living and controlled laboratory settings (Le Masurier and Tudor-locke 2003; Grant, Dall et al. 2008; Kang, Bassett et al. 2012); it has been found to most accurately record at walking speeds of 80-107 $m \cdot min^{-1}$ (Le Masurier, Lee et al. 2004; Feito, Bassett et al. 2012). This pedometer contains a horizontal, spring-suspended lever arm which moves up and down with vertical acceleration of the hips during walking behaviours. An electronic circuitry opens and closes within the pedometer and is designed to accumulate step counts which are displayed on a digital screen.

Each participant also completed the IPAQ-SF self-report, to report the frequency (days per week), duration (minutes), and level of intensity across a variety of different domains (Appendix 10). It was developed as an instrument to measure health-related physical activity in working age populations, and is considered a valid and reliable measure for monitoring population levels of physical activity (Craig, Marshall et al. 2003; Papathanasiou, Georgoudis et al. 2009; Van Der Ploeg, Tudor-Locke et al. 2010). The questionnaire consists of seven items which provide information within various intensity levels including aerobic activities (vigorous intensity), cycling activities (moderate intensity), walking activities, and sitting time undertaken during the previous week (Craig, Marshall et al. 2003; Lee, Macfarlane et al. 2011). The data were converted to metabolic equivalent (MET) scores according to the IPAQ scoring protocol (available at: http://www.ipaq.ki.se/ipaq.htm). The IPAQ-SF assesses frequency and duration of physical activity lasting for at least 10 minutes each session of walking (3.3 METS) and moderate (4 METS) and vigorous (8 METS) physical activity. Pedometer cut-points of 100 steps per minute corresponding to a minimal intensity ambulatory activity (3-MET activity) for both women and men or a range of 450–750 weekly MET minutes reflects 30 minute of moderate activity (Tudor-Locke, Sisson et al. 2005; Miller, Brown et al. 2006). The total time sitting in the last seven days was also recorded as an indicator of sedentary activity but this was not included as part of the summary physical activity score .

6.5.3 The Six Minute Walk Test (6MWT) "Functional exercise capacity"

Testing was conducted according to the guidelines from the American Thoracic Society. The walks were performed on a smooth level surface in an under-cover area, using a straight 30 metres marked off in 5 m segments by a piece of adhesive tape.

Technicians encouraged participants at fixed intervals during the walk with the standardized form of statements such as “you’re doing well”, “keep up the good work, and “do your best”, and the total distance walked was recorded in metres.

The 6MWT is a self-paced task that has been used to assess functional exercise capacity within a variety of chronic conditions, as well as in healthy adults (Hill, Wickerson et al. 2011; Soares and Pereira 2011). It is a practical and simple test which does not require expensive equipment or advanced training for technicians, and only requires a 30 metre walkway. The test involves asking people to walk the longest distance possible on an over-ground, hard surface for a period of 6 minutes.· It has been shown to have good reliability and validity when used to assess functional capacity (American Thoracic Society 2002; Alameri, Sanai et al. 2007).

6.5.4 Physical Activity Self-efficacy Scale

The five-item scale of self-efficacy (Appendix 11) for physical activity was administered to assess participants’ beliefs or their confidence in their physical ability to successfully achieve their goals in different situations (Marcus, Selby et al. 1992). Participants were presented with five common situations that potentially challenge their ability to participate in physical activity using a five point Likert scale. The questionnaire is scored by summing the 5 point Likert scale ranging from (1=not at all confident to 5= extremely confident) with a higher score reflecting greater self-efficacy for exercise. This scale has been shown to have acceptable two week test-retest reliability (0.90) and an internal consistency coefficient of 0.78 (Marcus, Selby et al. 1992).

6.5.5 Anthropometric and physiological Measures

During baseline, 12-week, and 3-month follow-up assessments, several secondary measures were obtained in the intervention and control groups including blood pressure (BP), body mass index (BMI), body fat (BF), waist circumference (WC), height and weight. Body fat percentage was formulaically measured using skinfold thickness (the Harpenden Skinfold Caliper W/Software) which was taken from four sites (triceps, biceps, subscapular, and suprailiac) according to recommended locations and technique

(Durnin and Rahaman 1967; Goacher, Lambert et al. 2012; Ulbricht, Neves et al. 2012). Three measurements to the nearest 0.1 mm were taken, and averaged then recorded on the report survey. Body fat was calculated by Linear Software (Durnin and Womersley) (Durnin and Womersley 1974) which is valid for people between 17 and 68 years old: body fat = (triceps + biceps + subscapular + suprailiac skinfolds) according to the participant's weight (kg) and age (Durnin and Rahaman 1967; Durnin and Womersley 1974).

Digital bathroom scales (Terraillon Lovely Classic Electronic Bath Scale) were used to measure weight to the nearest 0.1 kg without shoes and light clothing on a hard flat surface for accurate measurement. Before use, a 20 kg weight was placed on the scale to calibrate, and it was also ensured that the scale read 0.0 before any participant's weight was taken. A stadiometer was used to measure height (Seca 213 Portable Stadiometer) without shoes and light clothing to the nearest 0.1 cm. Participants were positioned on a hard flat level surface for accurate measurement. Blood pressure was measured with an Omron MX3 plus Blood Pressure Monitor (HEM-7200-E) (Coleman, Freeman et al. 2005) on three occasions with a rest period of one minute between measurements, then an average was taken and recorded based on previous study protocol (Morgan, Lubans et al. 2009). Waist circumference was measured using plastic tape by placing it around the waist at the level of the umbilicus (iliac crest) while participants were standing balanced on both feet, with both arms hanging freely. Three measurements to the nearest 1.0 mm were taken, averaged then recorded on the report survey.

6.6 Intervention protocol

The 12 week pedometer-driven walking intervention was based on self-regulation theory (SRT) (Baumeister, Gailliot et al. 2006) and included goal setting, feedback, educational material, and the use of a step calendar for self-monitoring. Self-regulation theory has been established as useful for understanding motivation, adherence to exercise, cognition, and as an effective strategy to increase physical activity as well as health behaviours. The major self-regulation mechanism works through three principles: self-monitoring, goal setting and activation and use of goal setting.

Several studies have demonstrated that self-regulation behavioural strategies were effective in changing walking behaviour among adults by setting a specific goal and/or self-monitoring interventions (Conn, Hafdahl et al. 2008; Dombrowski, Sniehotta et al. 2012; Sniehotta, Presseau et al. 2012). In addition, a large number of studies have used pedometer -based interventions to enhance and motivate individuals to increase their physical activity by using SRT strategy within a range of conditions including weight reduction (Richardson, Newton et al. 2008; Sugden, Sniehotta et al. 2008; Pal, Cheng et al. 2009) and improve pain in adults with MSD (Talbot, Gaines et al. 2003; Fontaine and Haaz 2007) with an aim to encourage increased habitual physical activity, and improve health-related quality of life. Therefore, the conclusions of previous research using this theory were chosen as the theoretical framework for this intervention.

6.6.1 Intervention group

Participants were instructed to wear a pedometer throughout waking hours for the 12-week intervention period. They were also provided with educational material (booklet and weekly emails) and feedback regarding their step counts thus giving participants knowledge of the health benefits of physical activity. The aim of this intervention was to motivate participants to increase their daily ambulatory activity level and improve health related outcomes. Participants were required to walk on at least five days per week to record pedometer steps per day for 12 weeks to meet evidence based international guidelines that recommend adults accumulate at least 30 minutes of moderate intensity activity, on at least five days per week, to achieve optimal health benefits (Haskell, Lee et al. 2007)**.** The pedometer intervention was used as a motivational and feedback tool, and consisted of a face-to-face session, pedometers for physical activity monitoring, educational material, goal setting, step count and feedback, and step calendar for self-monitoring. As participants all worked in the same plant, they were asked not to discuss the intervention they received with other workers. This recommendation was, however impossible to monitor. Details of the intervention are as follows.

6.6.1.1 Face-to-face session

After randomization, during the first week intervention participants attended a 30 minute education session on the health benefits of being physically active. Participants in the walking group (intervention) received a brief intervention group session of up to 70 minutes. The first 10 minutes of the intervention session covered a self-efficacy walk. The walking session was conducted with the principal investigator around the plant office. Participants wore the pedometer to record and monitor their steps during the 10 minute period in order to provide positive evidence of the participant's ability to increase physical activity and hence enhance their self-efficacy for exercise. The second part of the intervention was a 30 minute session focusing on physical activity behaviour change strategies including self-monitoring, goal setting, and improving physical activity behaviours. During this session, the physiotherapist asked the participants about their current physical activity and their barriers to further activity. The session also included discussion on how to change their walking behaviour and an explanation of the use of pedometers to set individual goals and how to maintain motivation. The last 30 minutes of the intervention session focussed on the education resource material (physical activity justification booklet of "Walk into Health" Toronto Public Health www.toronto.ca/ health/walkintohealth). During this session, participants were given an opportunity to express their ideas and discuss the benefits of physical activity and also benefits of using a pedometer. Briefly discussed were the minimum recommended guidelines for physical activity, and the goal of accumulating 10,000
steps per day This intervention session was based on the Back 2 Activity protocols (McDonough, Tully et al. 2010) and conducted by physiotherapists (including one with training in motivational interviewing), and the principal investigator.

6.6.1.2 Educational materials

Participants in both the walking (intervention group) and control groups also received standardized educational material (booklet) that consisted of written and graphical information describing the importance of walking as a physical activity for health benefits and prevention of disease (Li and Siegrist 2012; Rossi, Dikareva et al. 2012).

6.6.1.3 Goal setting

After baseline measurements, ambulatory activity level was obtained as previously described. Participants in the intervention group were told of their baseline mean steps by the principal investigator and shown how to set goals for walking for the first week of the intervention. The principal investigator also explained the significance of increasing physical activity after the baseline measurement, and of becoming more active. At the beginning of each week, participants received a weekly email reminder about their step-count goal for that week based on their baseline walking activity level. The goal for each participant was to gradually increase their levels of activity by 5% from their previous goal setting target with an overall aim to reach at least 10,000 steps per day at the end of the 12-week period. These targets were based on international guidelines for walking interventions (Tudor-Locke and Bassett 2004). However, those who reached 10,000 steps per day at any time during the programme were also encouraged to maintain and increase their physically active lifestyle. Each week participants also received a short cell phone text reminder from the principal investigator to offer feedback and counselling on their goal-setting for that week. This feedback was based on their submitted step count "log book" for that week.

6.6.1.4 Step count and feedback.

Participants in the intervention group also received permanent step-count feedback from the digital display of accumulated daily step counts on the pedometer monitor. On the first day of each week of the 12-week intervention participants also received personalized weekly emails to provide details about their walking progress and feedback on daily average step-count taken. To enhance social support, participants received additional health information, to encourage their adherence with the programme. In addition, participants were visited at their worksite on average 12 times over the duration of the intervention. During those visits, participants were given an opportunity to express their ideas, and discussions were aimed at motivating them to increase their physical activity levels. The researcher also had access to the participants' active logs.

6.6.1.5 Log book.

Participants in the walking group were given a diary (log book) which consisted of one page with two sides for each week period in which the participant filled out the type of activity undertaken and time spent in physical activity (Appendix 12). The first side included instructions on how to wear and use the pedometer and also incorporated the following five domains: the date, the time the pedometer was attached and also removed, and the total number of steps displayed on the pedometer at the end of each day, and total hours wearing a pedometer. The second side of the log book also included five domains: the date, type of non-walking activity, time pedometer was taken off, time pedometer was put on, and total minutes of non-walking activity. Participants were asked to record their periods of walking and note each day as to whether they were adhering to the programme, the time of day, duration of the walk, the week’s step-count goal, and the number of steps taken at the end of each day. The principal investigator added 150 steps to the daily total for every minute reported as non-walking activity (Miller, Brown et al. 2006). The reason for asking participants to record their non-walking activity was to translate it into “steps”, hence increasing their activity for that day. However, participants did not report any non-walking activity over the 12 week intervention. In addition, the log book was used to measure the walking programme adherence based on the number of days and hours that the pedometer was worn, and divided by the total number of intervention days.

6.6.2 Control group.

Participants randomly allocated to the control group were not asked to perform any kind of walking intervention over the 12 weeks. They attended a 30-minute education session with a physiotherapist, who gave a brief intervention focusing on the health benefits of being physically active, and were given educational activity material (physical activity booklet) at the first week of intervention. The same physical activity information was sent by weekly email to the control group participants, but they did not receive any text message during the study period. In addition, no goal setting was given to the control group. At the completion of the 12 weeks, and at the follow up at 24 weeks, these participants were required to wear the pedometer for one week to establish a weekly step count for comparison to baseline scores.

6.7 **Statistical Analysis**

A sample size calculation for effectiveness was not performed. As this was a feasibility study, we invited the pool of approximately 900 workers from a local meat processing plant on the South Island of New Zealand to consider participating in the study. Volunteer participants were screened and the study was begun when the convenience sample of 60 participants who meet eligibility criteria was recruited (N =30 participants in each group). Data were collected at three time points: baseline, 12 weeks, and follow-up measurement (3 months after the intervention). Data from the DW200 was downloaded into individual files for each participant for each week. In order for data to be included in the analysis participants were required to wear the pedometer for ≥ 10 hours per day for a minimum of five days per week. Steps per day were averaged by week. The change in the average number of steps per day over the 12-week programme was modelled for each individual who completed at least 10 weeks of the intervention.

The total weekly score for The IPAQ-SF was also calculated as (MET-min/wk) by adding the MET-minutes spent in moderate, vigorous, and walking activity per week to categorized participant into high level (at least 1500 MET-minutes per week), moderate level (at least 600 MET-minutes per week) or low who not meet the previous levels of physical activity (available at: http://www.ipaq.ki.se/ipaq.htm). Data from the eight sub-scale domains of health-related quality of life scale were extracted by using SF-36v2 scoring software which gives two summary measures; physical and mental component summary scores (PCS & MCS). Data items for the PCS and MCS summary scores were computed as T-scores in order to analyse and interpret the main score difference between groups compared to the mean score and standard deviation. In addition, the data from the self-efficacy for physical activity scale was scored by computing the mean score of all five items for each participant.

The feasibility and acceptability of using pedometers as an intervention to promote physical activity and improve health outcomes in this population were evaluated through participant satisfaction with the intervention by using survey questions to explore opinions regarding intervention components (Appendix 13). The questions included participation in the intervention, satisfaction with participation, and pedometer usage after completing the intervention. In addition, participants were asked to report any adverse events as well as provide any comments about the intervention procedure in a series of open-ended questions. Participants' adherence to the pedometer-driven walking programme was evaluated by analysing the pedometer logs to determine the number of days that the pedometer was worn and dividing by the total number of intervention days, attendance to the programme, and also the number of hours of use per day over the 12-week period. As this was a feasibility study, adherence to the pedometer assessment for the control group was also evaluated to determine if there was a difference in the adherence of participation between the groups to provide a clear picture for future study.

Descriptive statistics for the two groups were presented as means, confidence intervals and standard deviations for the continuous variables and absolute numbers and percentages for the categorical variables. Independent t-tests were used for nominal data to test for significant differences between the experimental and control groups at baseline. Data were analysed using Microsoft Excel® and Statistical Package for Social Sciences (SPSS®) version 21.0. The study data were examined for outliers and normality using the Shapiro-Wilk test and Normal Q-Q Plots. No outliers were identified and the data were normally distributed for each group and all variables at each time point ($p > 0.05$). Mauchly's test of sphericity demonstrated that the data did not violate assumptions of homogeneity of variance and sphericity.

A repeated measure, mixed model, ANOVA was used to examine pre- and post- between group differences in all outcomes at each follow-up time point of the study. Bonferroni confidence interval 95% (CI) was used on estimated marginal means at each follow-up time point to show the range of variation for between-group interactions. Within-group changes were assessed using pairwise comparisons for each variable. Since this was a feasibility study, effect sizes were calculated using standardised effect sizes for Cohen d values: 0.2 for small effect, 0.5 for medium effect, and 0.8 for large effect (Cohen 1988). An intention to treat protocol was performed by replacing missing values with the group mean at 12 and 24-week follow-up time points, giving a final analysis of 29 participants in each group (Shao and Zhong 2003; Bubbar and Kreder

2006, Warren et al. 2009). The independent T-test was applied to detect differences between groups at baseline for all 58 participants.

7 Chapter Seven

Use of pedometer-driven walking to promote physical activity and improve health-related quality of life among meat processing workers.

Results and discussion

7.1 Recruitment and follow-up

A total of 95 (38 male and 57 female) individuals volunteered to participate in this study and were screened by the principal investigator Suliman Mansi (SM) for eligibility. Thirty-five participants did not meet the inclusion criteria as their final average step count was more than the cut-off criterion for inclusion (≥ 7,500 steps per day). Two participants dropped out before randomization; fifty-eight (58/95; 61%) participants were randomized to either the intervention or the control group. Fifty three (53/58; 91.1%) participants completed all of the assessment follow up points. Five participants dropped out after randomization: three from the control group completed only the baseline assessment, while two participants dropped out from the intervention group. In the intervention group, one participant provided pedometer data for three weeks, and the other completed six weeks of pedometer data. Figure 9 displays participant flow through the study.

7.2 Demographic data

Demographic characteristics are shown in Table 16. The mean age of the participants was 41.6 years (SD= 13.6; range: 18-65); the majority were female (34/58; 58.6%); most classified themselves as NZ European (33/58; 56.9%); and mean BMI was 29.2 kg/m^2 (SD= 6.0, range 19.6 to 43.6). The majority (70.7%; 41/58) of participants had received high school education and 34.5 % (20/58) were employed in the slaughter board department. The independent T-test was applied to detect differences between groups at baseline for all 58 participants. There were no significant differences in baseline data between groups, as shown in Table 17.

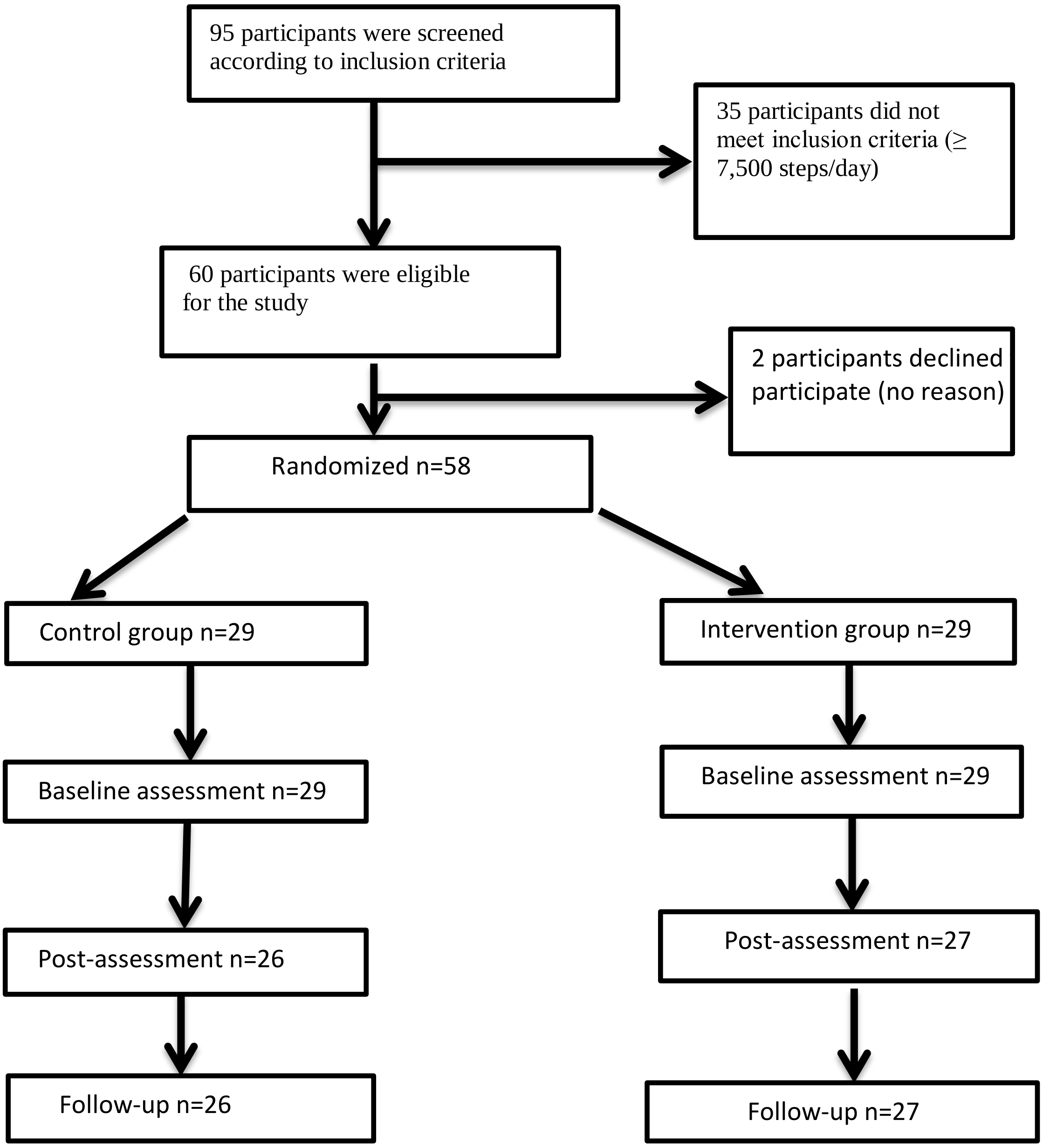

Figure 7: Flow of participants through the study

Table 16: Baseline characteristics of participants, pedometer intervention and control.

Characteristic	Randomised (n = 58)	
Participants	Intervention (n = 29)	Control (n = 29)
Age (yr), mean **(SD)** Height (cm), mean **(SD)**	43 (14.9) 164.4 (11.2)	40 (12.2) 165 (10.2)
Body Mass Index (kg/m^2) **(SD)**	29.9(7.2)	28.3(4.4)
Gender, n males **(%)**	10 (34.5)	14 (48.3)
Ethnicity, n (%)		
NZ European	19 (65.5)	14 (48.3)
NZ Maori	4 (13.8)	4 (13.8)
Pacific Island	1 (3.4)	7 (27.1)
Asian	1 (3.4)	3 (10.3)
African	3 (10.3)	1 (3.4)
Other	1 (3.4)	0 (0.0)
Education, n (%)		
High School	20 (69)	21 (72.4)
College or University	9 (31)	8 (27.6)
Department's category, n (%)		
Slaughter board	11(37.9)	9 (31)
Lambcuts	4 (13.8)	5 (17.2)
Beef House	2 (6.9)	6 (20.7)
Small Goods	4 (13.8)	1 (3.4)
Boning Room	2 (6.9)	2 (6.9)
Management Meat Inspector	4 (13.8) 2 (6.9)	6 (20.7) 0 (0.0)

SD= standard deviation

Table 17: Baseline characteristics of participants

Characteristic	Randomised (n = 58)		
	Intervention (n = 29)	Control (n = 29)	P value
Step-count, mean (SD)	5993 (1234)	5788 (1172)	0.519
Days	6.8(0.44)	6.8(0.46)	0.774
Hours	13.7(1.4)	14.2(1.4)	0.141
Weight (Kg)	80.2(16.9)	76.9(13.9)	0.418
SBP (mm Hg)	125.1(16.3)	122.4(11.3)	0.474
DBP (mm Hg)	76.3(9.6)	75.0(6.9)	0.568
Body fat (mm)	29.6(6.9)	27.7(6.9)	0.306
BMI (kg/m^2)	29.9(7.2)	28.3(4.4)	0.299
WC (mm)	98.9(12.7)	93.5(12.1)	0.105
6MWT (cm)	555(71.9)	554(69)	0.969
W.MET (min/wk)	182(140)	168(118)	0.694
T.MET (min/wk)	566(184)	530(250)	0.532
Sitting time (min/wk)	224(93)	232(84)	0.758
Self-efficacy (1-5 point)	2.6(0.61)	2.7(0.70)	0.555
PCS (0-100 point)	49.2(7.2)	50.5(8.0)	0.531
MCS (0-100 point)	50.3(8.0)	51.0(5.7)	0.716

WMET= walking metabolic equivalent, Total MET= total metabolic equivalent, PCS= physical component score, MCS= mental component score, 6MWT= 6 minute walk test, DBP= diastolic blood pressure, SBP= systolic blood pressure, WC= waist circumference, SD= standard deviation.

7.3 **Feasibility of using pedometers**

The primary aim of this study was to examine the feasibility of using a pedometer-based intervention to increase physical activity and improve health-related outcomes over 12-week periods. Based on the pedometer data logs, and satisfaction survey questions with 5-point scales, shown in Table 18 and 19, these data show a high level of adherence: 27 out 29 participants completed the programme and surveys, giving an adherence rate of 93.1% for the pedometer intervention programme and 90% (26/29) for the control group for both the 12-week intervention and the 24-week follow-up.

Adherence to pedometer usage was measured by the number of pedometer logs returned and the completeness of each diary. According to returned logs, participants wore their pedometers an average of 6.8 out of seven days (97%) in both the pedometer group and control group during the seven-day assessment at three time point periods. Of the 27 participants from the intervention group who returned pedometer logs; five participants recorded their steps on the record log book for 11 weeks; one participant walked for 10 weeks while 21 participants walked for 12 weeks. The pedometer logs also show a high adherence for daily step data recorded with a mean of 6.7 (± 0.2) days out of 7 over the 12-week study period. The mean number of hours of use per day was 13.8 ± 0.5 hours during the 12-week period. There were no differences in daily pedometer wear time between pedometer group (13.7 hours per day) and control group (13.9 hours per day) during the three time point assessments ($p=0.751$).

Table 18: Intervention and control groups: Participant Adherence

Feasibility variables	Rates (%)
Intervention adherence **Control adherence** **Participants who completed the intervention**	27/29 93.1% 26/29 90.0% 53/58 91.4%
Participants who wore the pedometer and filled in the record log sheet for: **12-week** **11- week** **10-week**	 21/27 77.8% 5/27 18.5% 1/27 3.7%
Time participants wore pedometer (days)	6.7 ± 0.2 / 7 days
Time participants wore pedometer (hours/day)	13.7 hours per day

Note: Adherence to the pedometer-driven walking programme was evaluated by analysing the pedometer logs to determine the number of days that the pedometer was worn and divided by the total number of intervention days, and also to determine the number of hours of use per day over 12-week periods.

Table 19 present the scores on satisfaction survey for intervention participants. Satisfaction scores with the intervention were high overall with a median of 4 or 5 out of 5 on a 5-point likert scale for all the questions. Overall, the majority of participants reported that the pedometer was easy to use, while 17/27 participants reported that supporting materials helped them increases their daily physical activity. The majority of participants indicated that they would continue to use the pedometer to increase their activity in the future, and all participants reported using the pedometer for 10 weeks or greater with no serious adverse effects reported. The majority of participants agreed that the pedometer-based intervention was a useful means of self-monitoring in prompting and increasing their level of physical activity. Participants were visited at their worksite on average 12 times over the duration of the intervention. Very few problems with pedometer use (n = 3) were reported; all the reported problems related to its memory deficits. However, participants did not raise any concerns about the intervention components, which can therefore be seen as a feasible mechanism for delivering a walking intervention on a worksite.

Table 19: Intervention Group: Participant Satisfaction

Q: How difficult was it to use the pedometer?				
Median response was "4 - very easy"				
None	2/27	2/27	14/27	9/27
Very difficult	Slightly difficult	Moderate easy	Very easy	Extremely easy
Q: How useful were the supporting materials?				
Median response was "4 - very useful"				
None	None	5/27	17/27	5/27
Not at all useful	Slightly useful	Moderately useful	Very useful	Extremely useful
Q: How effective was the pedometer in motivating you to become more active?				
Median response was "4 - very effective"				
1/27	1/27	5/27	15/27	5/27
Not at all effective	Slightly effective	Moderately effective	Very effective	Extremely effective
Q: How easy was it to achieve the recommended targets?				
Median response was " 4 - very easy"				
1/27	4/27	8/27	12/27	2/27
Very difficult	Slightly difficult	Moderately easy	Very easy	Extremely easy
Q: For how many weeks did you use the pedometer				
Median response was "5 - 10 to 12 weeks"				
None	None	None	1/27	26/27
1-2 weeks	2-4 weeks	4-7 weeks	7-10 weeks	10-12 weeks
Q: How committed are you to maintaining a physically active lifestyle?				
Median response was "4 - very much committed"				
None	1/27	4/27	15/27	7/27
Not at all committed	Slightly committed	Moderately committed	Very much committed	Extremely committed
Q: Will you continue to use the pedometer to monitor your step-counts?				
Median response was " 5 - yes"				
2/27	1/27	2/27	6/27	16/27
No	Probably not	Maybe	Probably	Yes

7.4 Change in primary outcomes

7.4.1 Step-count

Comparisons of physical activity levels at baseline, twelve-week, and 24-week follow-ups are shown in Table 20. Repeated measures ANOVA analysis showed a statistically significant time by group interaction identified in daily step count over time ($p<0.005$; $F=142.80$). Within group pairwise comparisons revealed the step-count increased from a mean of 5993 (± 1234) steps per day during week 0 (baseline) to 9792 (± 2053) steps per day by week 12 intervention $p<0.005$, or an absolute increase of mean difference MD= 3799 steps (95% CI, 3225 to 4371) in the intervention group. This increase in step counts remained significant within the intervention group ($p<0.005$; MD= 3651, 95% CI, 2950 to 4354) at the 24-week follow-up representing a 59% increase over baseline scores. The control group also showed a significant increase in daily step-count ($p= 0.013$) from baseline to12 weeks intervention (MD= 763; 95% CI, 137 to 1388) steps per day (Table 20). A univariate analysis of variance showed a significant difference in step-count between the groups at 12 weeks intervention (mean group difference MGD= 1723; 95% CI, 1188 to 2258, $p<0.005$, effect size (ES)= 1.94) and 24 weeks follow-up ($p<0.005$, MGD= 2275; 95% CI, 1805 to 2745) (Table 22). Mean daily steps increased by 59% between weeks 0 and 12 (in the intervention group) indicating that the step goals set (to increase by 5% per week) were generally achieved. Table 21 and Figures 10 and 11 represent the change in step-count at each stage of the programme showing the mean value for each stage.

7.4.2 Self-reported physical activity

Data in both intervention and control groups for self-reported physical activity (IPAQ-SF) were converted into metabolic equivalent minutes per week (See: Section 6.5.2). Repeated measures ANOVA revealed a significant time by group effect for walking metabolic equivalent (W.MET): $p<0.005$; $F= 88.26$. Improvements in W.MET were significant from baseline (182 ± 140 MET) to 12 weeks intervention (1035 ± 444 MET) ($p<0.005$, MD= 853.6, 95% CI, 660 to 1047) within the intervention group, compared to the control group ($p= 0.545$, MD= 19.9; 95% CI, -63 to 103; Table 20).

A univariate analysis results showed a significant difference between-groups in the mean W.MET after 12 weeks post-intervention ($p<0.005$, MGD= 430 MET; 95% CI, 338 to 522, ES= 2.57) and this difference remained significant at the 24-week follow-up ($p<0.005$, MGD= 550; 95% CI, –472 to 629; Table 22).

In addition, the total metabolic equivalent (T.MET) for time spent in vigorous, moderate and walking physical activity also showed a statistically significant time by group interaction ($p<0.005$, F= 54.67). Within the intervention group, T.MET also significantly increased from a mean of 466 (± 184) during baseline to 1469 (± 524) by week 12 post-intervention ($p<0.005$, MD= 903; 95% CI, 683 to 1124) and 24 weeks follow-up ($p<0.005$, MD= 817, 95% CI, 630 to 1003) with no significant changes in the control group (P= 0.889, MD= 7.8, 95% CI, -146 to 162) at 12 weeks intervention. A univariate analysis showed a statistically significant between-group difference after the12 week intervention ($p<0.005$, MGD= 484, 95% CI, 362 to 606; ES= 2.59) and at the 24 weeks follow-up ($p<0.005$, MGD= 826, 95% CI, 622 to 1030).

Table 20: Primary outcome measures: Mean (SD) of groups changes, and mean differences within group for outcomes between baseline and follow-up periods

12 weeks changes	Intervention n=29				Control n=29			
	Baseline	12 weeks	Means Difference (95% CI)	P value	Baseline	12 weeks	Means Difference (95% CI)	P value
Step-count	5993 (1234)	9792 (2053)	3799 (3225 to 4371)	0.005	5788 (1172)	6551(1154)	763 (137 to 1388)	0.013
W.MET (min/wk)	182 (140)	1035 (444)	853 (659 to 1047)	0.005	168 (118)	188 (135)	20 (-63 to 103)	0.545
Total MET (min/wk)	566 (184)	1469 (524)	903 (683 to 1124)	0.005	530 (250)	538 (254)	8 (-146 to162)	0.898
PCS(0-100)	49.3 (7.2)	53.3 (5.3)	4.0 (0. 9 to 7.1)	0.008	50.5 (8.1)	50.0 (7.1)	-0.5 (-3.5 to 2.5)	0.670
MCS(0-100)	50.3 (8.0)	52.7 (5.2)	2.4 (-0.1 to 5.7)	0.082	51.0 (5.8)	51.7 (7.1)	0.7 (-2.0 to 3.5)	0.519
6MWT (cm)	555 (72)	587 (69)	32.6 (20.3 to 44.9)	0.005	554 (69)	569 (74)	14.9 (-6.0 to 36.0)	0.081
24 weeks changes	Intervention n=29				Control n=29			
	Baseline	24 weeks	Means Difference (95% CI)	P value	Baseline	24 weeks	Means Difference (95% CI)	P value
Step-count	5993(1234)	9645(1906)	3652 (2950 to 4354)	0.005	5788 (1172)	6266 (1648)	478 (-306 to1263)	0.396
W.MET (min/wk)	182 (140)	972 (383)	790 (615 to 964)	0.005	168 (118)	180 (133)	12 (-65 to 89)	0.701
Total MET (min/wk)	566 (184)	1383 (402)	817 (630 to 1003)	0.005	530 (250)	520 (246)	-10 (-190.7 to170)	0.893
PCS(0-100)	49.3 (7.2)	52.8 (4.6)	3.5 (0.5 to 6.5)	0.018	50.5 (8.1)	50.9 (6.9)	0.38 (-4.22 to 4.99)	0.833
MCS(0-100)	50.3 (8.0)	53.1(5.4)	2.7 (-1.0 to 6.5)	0.074	51.0 (5.8)	51.8 (6.6)	0.8 (-3.2 to 5.0)	0.599
6MWT (cm)	555 (72)	584 (67)	29.4 (9.4 to 49.4)	0.001	554 (69)	562 (74)	8.2 (-16.7 to 33.2)	0.409

WMET= walking metabolic equivalent, total MET= total metabolic equivalent (extracted from International Physical Activity questionnaire), PCS= physical component score, MCS= mental component score, 6MWT= 6 minute walk test

Table 21: Intervention group: Changes in step counts over 12 the weeks of the programme

Week	Minimum steps	Maximum steps	Mean	Std. Deviation	% Change
Week 1	3773	8811	6400	1507	6.79%
Week 2	3903	9070	6790	1438	6.09%
Week 3	3747	8927	7143	1651	5.15%
Week 4	3988	9975	7606	1454	6.48%
Week 5	4321	10285	7949	1685	4.50%
Week 6	4540	10137	8101	1655	1.91%
Week 7	4511	10839	8548	1742	5.51%
Week 8	4875	11126	8651	1894	1.20%
Week 9	4953	11796	9116	1950	5.38%
Week 10	5396	12643	9355	2119	2.62%
Week 11	5538	12940	9700	2159	3.69%
Week 12	5704	13427	9917	2156	2.23%

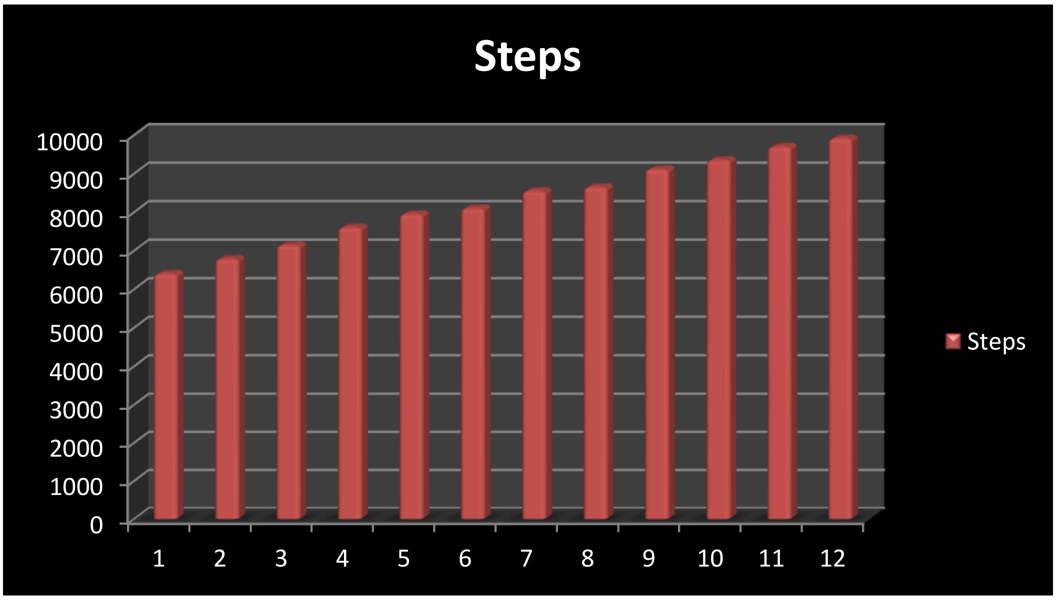

Figure 8: Intervention Group: Mean number of steps per day over the 12 week intervention

7.4.3 Quality of life SF-36v$_2$ summary scores

At baseline there was no statistically significant difference in quality of life SF-36v$_2$ summary scores between groups, with no significant differences between physical component score (PCS) and mental component score (MCS) at baseline (p= 0.531 and p= 0.716 respectively; Table 17). A repeated measures ANOVA found no significant time by group interaction in MCS score over time (p= 0.580; F= 0.536). Within group pairwise comparisons revealed the MCS score increased from a mean of 50.3 ± 8.0 units at baseline to 52.7 ± 5.2 by week 12 of the intervention (p= 0.082, MD= 2.4 unit; 95% CI, -0.1 to 5.7) in the intervention group with no significant increases in the control group (MD= 0.7 unit; p = 0.519, 95% CI, -2.0 to 3.5; Table 20). There was no significant difference in MCS score between the intervention group and the control group at week 12 of the intervention (p = 0.904, MGD = 0.2; 95% CI, -2.3 to 2.6, ES = 0.15) or at the 24-week follow-up (p = 0.603, MGD = 0.5; 95% CI, -1.4 to 2.4; Table 22).

There was no statistically significant time by group interaction in PCS scores (p = 0.072, F = 2.70). Despite the non-significant interaction differences in PCS scores, pairwise comparisons results indicate that the PCS scores significantly increased from a mean of 49.3 during baseline to 53.3 by week 12 post-intervention or an absolute increase of 4.0 units (p = 0.008, 95% CI, 0. 9 to 7.1) in the intervention group. This increase in PCS scores remained significant at the 24-week follow-up (p = 0.018,MD=3.5; 95% CI, 0.5 to 6.5) with a slight decrease in the control group (p = 0.670, MD= -0.5, 95% CI, -3.5 to 2.5; Table 20). There were no significant between-group differences in PCS scores (p = 0.454; MGD= 0.1, 95% CI, -1.6 to 3.6; ES= 0.51) after the 12 week intervention and also no significant changes (p= 0.208, MGD = 1.3; 95% CI, -0.7 to 3.3) at the 24-week follow-up (Table 22).

7.4.4 The six minute walk test

Analysis of the six minute walk test (6MWT) demonstrated a non-significant time by group interaction (p = 0.130; F=2.05). However, as seen in Table 20, mean 6MWT increased over time for the intervention group, with a significant increase between baseline and after the 12-week intervention (p<0.005, MD= 32.6; 95% CI, 20.3 to 44.9) and at the 24-week follow-up (p = 0.003, MD= 29.4, 95% CI, 9.4 to 49.5). No significant changes over time were shown for the control group (p = 0.081, MD = 14.9;

95% CI, -6.0 to 36.0). Univariate analysis revealed that mean 6MWT was not significantly different between groups at 12 weeks intervention (p = 0.473, MGD= 10; 95% CI, -17 to 36, ES = 0.14) or at the 24-week follow-up (p = 0.206, MGD = 14; 95% CI, -8 to 35; Table 22).

Table 22: Primary outcome measures: Mean differences between groups for primary outcomes at 12 and 24 weeks

Variable	Week-12		Week-24			
	Difference between group means (95% CI)	P	Difference between group means (95% CI)	P	Cohen's d	Time* group
Step-count	1723 (1188 to 2258)	<0.005	2275 (1805 to 2745)	<0.005	1.945	<0.005
6MWT (cm)	10 (-17 to 36)	0.473	14 (-8 to 35)	0.206	0.257	0.130
W.METs (min/wk)	430 (338 to 522)	<0.005	550 (472 to 629)	<0.005	2.570	<0.005
Total. MET (min/wk)	484 (362 to 606)	<0.005	610 (511 to 709)	<0.005	2.591	<0.005
MCS (0-100)	0.2 (-2.3 to 2.6)	0.904	0.5 (-1.4 to 2.4)	0.605	0.156	0.580
PCS(0-100)	0.1 (-1.6 to 3.6)	0.454	1.3 (-0.7 to 3.3)	0.208	0.517	0.072

6MWT=six minute walk test, W.MET=walking metabolic equivalent, Total. MET=total metabolic equivalent, MCS=mental component score, PCS=physical component score.

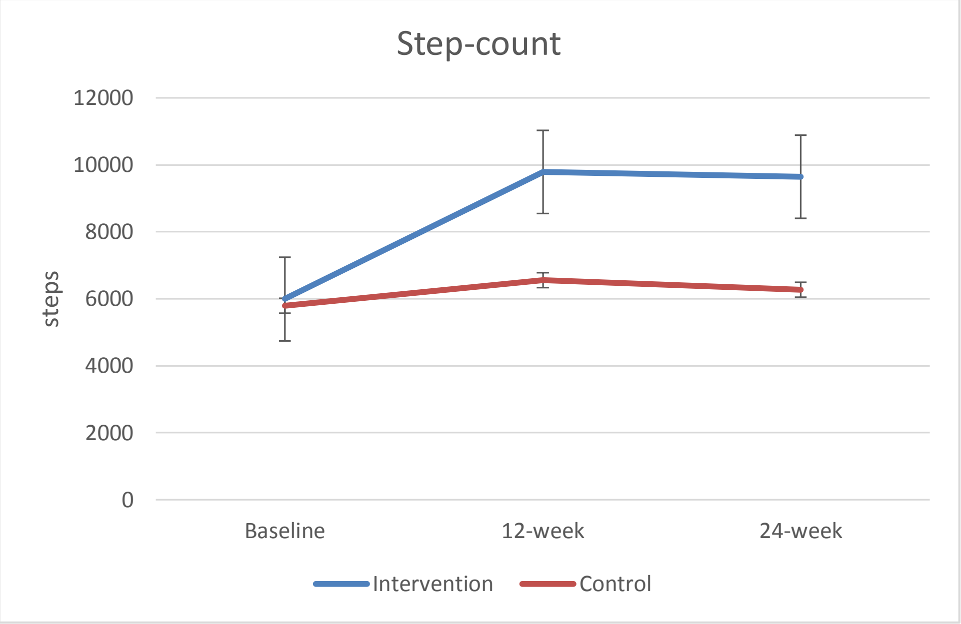

Figure 9: Step-count scores at the three measurement periods (Group Means)

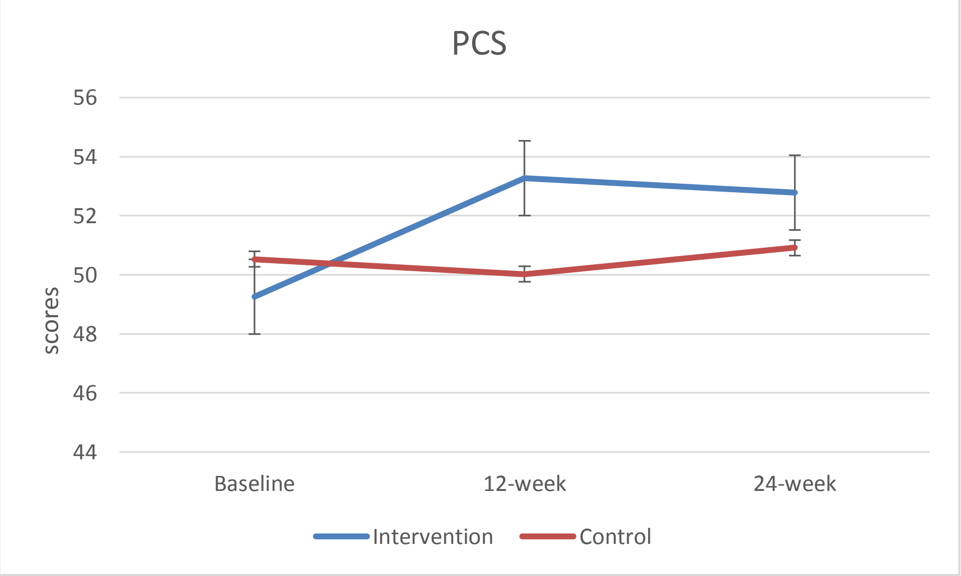

Figure 10: Physical components scores at the three measurement periods (Group Means)

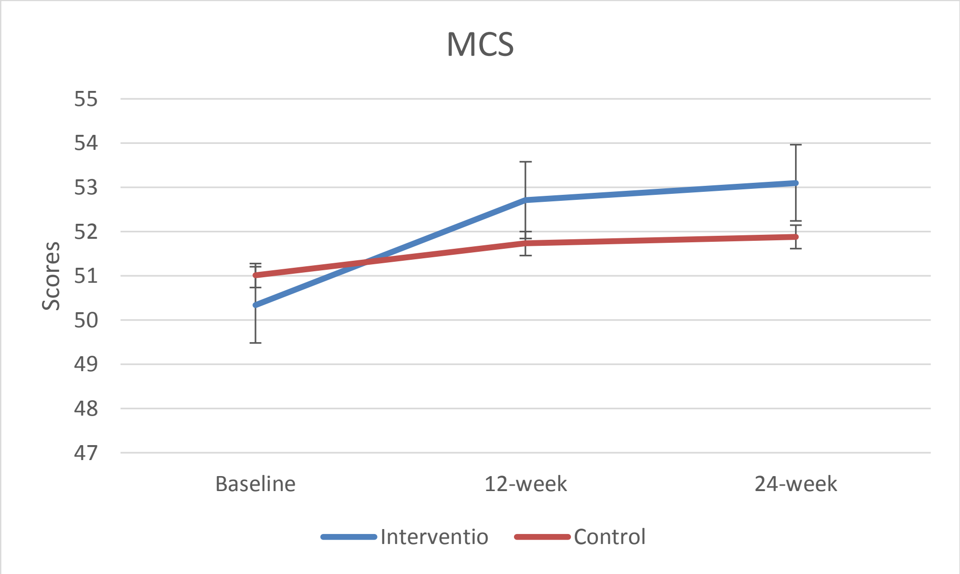

Figure 11: Mental components scores at the three measurement periods (Group Means)

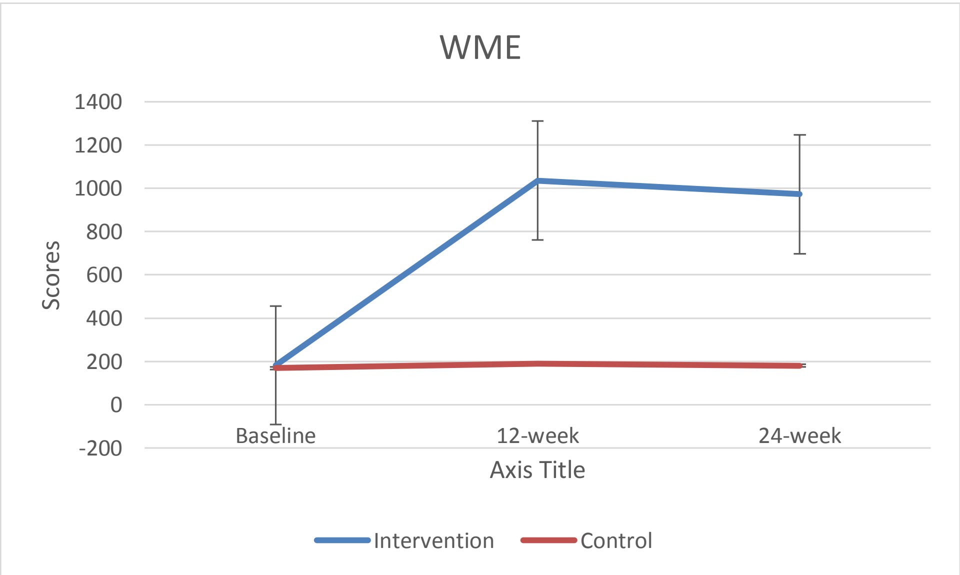

Figure 12: Walking metabolic equivalent scores at the three measurement periods (Group Means)

7.5 Change in secondary outcomes (Table 23 and 24)

Between baseline and the completion of the 12-week intervention, significant improvements were observed in secondary health outcomes in the intervention group (Table 24). For body fat (BF), there was a significant decrease representing a reduction of 1.7 kg/m2 (95% CI; -2.9 to -0.4, p = 0.006; ES = 0.08) in the intervention group compared to the control group (p = 0.340; MD = -0.4, 95% CI, -1. 2 to 0.6). There were no significant difference in BF between intervention and control groups (p = 0.338, MGD= 1.2; 95% CI, -1.3 to 3.7) 12 weeks post-intervention (Table 23).

There was also a significant decrease in BMI from baseline to 12 weeks post-intervention (p = 0.047, MD= -1.1; 95% CI, -2.3 to 0.1) in the intervention group compared to the control group (p = 0.856, MD = 0.1, 95% CI, -0.9 to 1.1; Table 24). There was no significant between-group difference in changes to BMI (p = 0.314). For both groups, there was a decrease in systolic (SBP) and diastolic blood pressures (DBP) at 12 weeks, with larger decreases apparent in the intervention group: mean change from baseline to 12 weeks post-intervention was significantly decreased in SBP (p = 0.030, MD= -3.5; 95% CI; -7.4 to 0.4), and non-significantly decreased in DBP (p =0.165, MD= -2.1, 95% CI, -4.7 to 0.6) compared to the control group (p = 0.407, MD= -1.1, 95% CI , -4.7 to 2.4 and p = 0.252, MD= -1.0, 95% CI ,-3.2 to 1.2, respectively; Table 24). No significant change was observed between groups in SBP or DBP (p = 0.524, and p = 0.596 respectively at 12 weeks (Table 23).

There was also a non-significant decrease in weight in the intervention group (p = 0.133, MD= -1.7, 95% CI, -3.9 to 0.4) compared to the control group (p = 0.886, MD=0.2 95% CI, -2.9 to 3.3) at 12 weeks. While there was no significant change between groups for weight reduction (p = 0.399), there was a significant reduction in waist circumference in the intervention group (p = 0.029, MD = -1.7, 95% CI, -3.8 to 0.2). Small effect sizes were obtained for BMI (ES=0.094), BF (ES=0.081), DBP (ES=0.032), SBP (ES=0.030), and weight (ES=0.093) and moderate effect sizes were obtained for self-efficacy (ES=0.533) and WC (ES=0.272).

Table 23: Secondary outcome measures: Mean differences between groups at 12 and 24 weeks

Variable	Week 12		Week 24		
	Difference between group means (95% CI)	P	Difference between group means (95% CI)	P	Cohen's *d*
BMI (kg/m^2)	1.1 (-1.0 to 3.2)	0.314	0.9 (-0.8 to 2.6)	0.292	0.094
Self-efficacy (1-5 point)	0.1 (-0.1 to 0.3)	0.445	0.2 (0.1 to 0.4)	0.016	0.533
Body fat (mm)	1.2 (-1.3 to 3.7)	0.338	0.9 (-1.1 to 2.9)	0.353	0.081
W.C (mm)	4.4 (-0.2 to 8.4)	0.058	4.0 (0.3 to 7.7)	0.032	0.272
SBP (mm Hg)	1.5 (-3.2 to 6.2)	0.524	0.8 (-2.8 to 4.4)	0.660	0.030
DBP (mm Hg)	0.7 (-1.1 to 3.5)	0.596	0.4 (-1.7 to 2.5)	0.722	0.032
Weight (kg)	2.4 (-3.2 to 7.9)	0.399	1.9 (-2.5 to 6.4)	0.382	0.093

BMI=body mass index, WC= waist circumference DBP= diastolic blood pressure, SBP= systolic blood pressure

Table 24: Secondary outcome measures: Mean (SD) of group changes, and mean differences within groups for outcomes between baseline and follow-up periods

12 week changes	**Intervention n=29**				**Control n=29**			
	Baseline	12 weeks	Mean Difference (95% CI)	P value	Baseline	12 weeks	Mean Difference (95% CI)	P value
BMI (kg/m^2)	29.9 (7.2)	28.8 (6.8)	-1.1 (-2.3 to 0.1)	0.047	28.3 (4.4)	28.4 (4.3)	0.1 (-0.9 to 1.1)	0.856
S-E (1-5 point)	2.6 (0.6)	3.1(0.5)	0.5 (0.1 to 0.9)	0.007	2.7 (0.7)	2.8 (0.5)	0.1 (-0.2 to 0.4)	0.329
Body fat (mm)	29.6 (6.9)	27.9 (6.9)	-1.7 (-2.9to -0.4)	0.006	27.7 (6.9)	27.4 (6.5)	-0.4 (-1.2 to 0.6)	0.340
WC (mm)	98.9 (12.8)	97.1(12.4)	-1.7 (-3.8 to 0.2)	0.029	93.5 (12.1)	93.8 (12.3)	0.2 (-1.3 to 1.8)	0.692
SBP (mm Hg)	125.1 (16.4)	121.6 (12.7)	-3.5 (-7.4 to 0.4)	0.090	122.4 (11.4)	121.2 (9.4)	-1.1 (-4.7 to 2.4)	0.407
DBP (mm Hg)	76.3 (9.7)	74.2 (7.3)	-2.1 (-4.7 to 0.6)	0.068	75.0 (6.7)	74.0 (5.2)	-1.0 (-3.2 to 1.2)	0.252
Weight (kg)	80.3 (16.9)	78.5(16.2)	-1.7 (-3.9 to -0.4)	0.133	76.9 (16.2)	77.1 (12.8)	0.2 (-2.9 to 3.3)	0.886
24 week changes	Intervention n=29				Control n=29			
	Baseline	24 weeks	Mean Difference (95% CI)	P value	Baseline	24 weeks	Mean Difference (95% CI)	P value
BMI (kg/m^2)	29.9 (7.2)	29.0 (6.7)	-0.1 (-2.3 to 0.3)	0.062	28.4 (4.4)	28.5 (4.1)	0.1 (-1.2 to 1.4)	0.841
S-E (1-5 point)	2.6 (0.6)	3.1 (0.5)	0.5 (0.2 to 0.8)	0.002	2.7 (0.7)	2.6 (0.5)	-0.1 (-0.4 to 0.3)	0.691
Body fat (mm)	29.6 (6.9)	27.9 (6.4)	-1.7 (-3.1 to -0.3)	0.011	27.8 (6.9)	27.6 (6.1)	-0.2 (-1.3 to 0.9)	0.661
WC (mm)	98.9 (12.8)	97.0 (12.3)	-1.9 (-3.9 to 0.1)	0.060	93.5 (12.1)	93.7 (12.2)	0.2 (-1.3 to 1.7)	0.741
SBP (mm Hg)	125.1 (16.4)	120.9 (11.4)	-4.1 (-8.6 to 0.2)	0.030	122.4 (11.4)	121.5 (9.6)	-0.9 (-4.8 to 3.0)	0.572
DBP (mm Hg)	76.3 (9.7)	74.1 (6.1)	-2.2 (-4.5 to 1.1)	0.165	75.1 (6.7)	74.4 (6.2)	-0.6 (-3.8 to 2.5)	0.608
Weight (kg)	80.3 (16.9)	78.7 (16.2)	-1.6 (-4.1 to 0.9)	0.330	76.9 (16.2)	77.5 (12.1)	0.6 (-2.6 to 3.8)	0.646

BMI=body mass index, WC= waist circumference, DBP= diastolic blood pressure, SBP= systolic blood pressure, S-E= self-efficacy

7.6 Discussion

This study used a 12 week pedometer-driven walking intervention conducted at a large meat processing plant in the rural South Island of New Zealand. The 12 week period was chosen based on the literature review (Chapter 4) regarding pedometer-based intervention within a workplace setting, reporting that workplace pedometer interventions commonly run for 1-12 months with a median duration of 12 weeks. This was considered sufficient duration to determine whether there would be significantly increased physical activity and improved health-related outcomes. Consistent with this, a recent systematic review conducted in a workplace setting (To, Chen et al. 2013) reported that most successful pedometer-based intervention run for 3-4 months to increase physical activity and improve health outcomes (Chan, Ryan et al. 2004; Thomas and Williams 2006; Borg, Merom et al. 2010; Freak-Poli, Wolfe et al. 2011; Hess, Borg et al. 2011; Aittasalo, Rinne et al. 2012). The purpose of this study was to examine the feasibility and acceptance of using the pedometer-driven walking intervention programme. It is an integral part of future plans for a randomized controlled trial which will assess the effectiveness of the walking intervention in increasing physical activity and improving health related quality of life among employees in a meat processing industry. In this study of participants with low physical activity levels, it was demonstrated that a workplace based pedometer-driven walking intervention programme was acceptable and achieved high adherence rates; it was also found to be feasible to recruit suitable adults from the workplace into a walking study. The intervention and methodology also proved successful based on the results of study adherence and the satisfaction survey, as well as the large effect size for pedometer intervention on step-count level. In addition, no major issues arose within this setting with respect to wearing and use of pedometers to provide feedback towards step count goals.

7.6.1 Adherence with the intervention

Participants reported a high rate of adherence and retention to the walking programme with 93% from the intervention group and 90% from those assigned to the control group over the initial 12-week period. Results show a higher rate of adherence compared with previous pedometer interventions reported in a variety of workplace populations, including university employees (Gilson, McKenna et al. 2007; Puig-

Ribera, McKenna et al. 2008; Thøgersen-Ntoumani, Loughren et al. 2013), Home Depot workers (Dishman, DeJoy et al. 2009), and office workers (Maruyama, Kimura et al. 2010; Aittasalo, Rinne et al. 2012). For example, Ribeiro et al. (2014) conducted a study on workplace interventions to increase physical activity and reported 80% retention at 3 months, while Pal et al. (2009) reported 86% adherence to a pedometer-driven walking programme in overweight and obese women employed in the newspaper industry in Australia. The difference between our results and those of Pal et al. (2009) may be due to location of the intervention environment. Pal et al. (2009) had minimal contact between participants and researcher (once a month), low levels of social support, and participants' physical activity levels at baseline were generally higher than our study (10265 steps per day). A recent pedometer working study (Thøgersen-Ntoumani, Loughren et al. 2013) reported 73% retention after a 16-week intervention. This study compared two intervention groups across different seasons (spring and winter) throughout three day's during lunchtime (30 minute) and weekend days. The authors concluded that the participation during lunchtime was detrimental to retention rates, due to participants' tendency to work or pursue other commitments during their lunch breaks.

In contrast, a recent study by McDonough et al. (2013) reported a similar rate of adherence (93%) to the current study in the chronic low back pain (CLBP) population throughout the 12-week intervention. It is important to highlight that McDonough and colleagues (2013) used similar methodology as used in the current study such as face-to-face orientation session, 10 minute walk self-efficacy, and social support by regular contact. On the other hand, a review of 26 pedometer-based studies (8 randomized controlled trials and 18 observational studies) across various settings, including five within workplace by (Bravata, Smith-Spangler et al. 2007) found nine studies reported 100% adherence, and five studies reported 83% rate of adherence, while the rest reported an average 80% of adherence. However, they reported a high level of attrition within workplace studies due to the recruitment of participants who were already physically active. This is consistent with a recent systematic review of randomized controlled trials of pedometer-based interventions within workplace populations that also reported a high level of attrition ranging from 15 to 40% (Freak-Poli, Cumpston et al. 2013). In addition, another systematic review evaluated participant retention rates with physical activity intervention within different settings, reporting 76.2% retention rates (ranging from 57 to 94%) for physical activity interventions within workplace settings (Waters, Galichet et al. 2011). The authors concluded that high dropout might be due to work environment and job commitments.

High adherence in the current study might be due to the high level of regular contact between participants and the principal researcher; being based on site, visiting participants in their own environment in order to maintain follow-up contact in the study setting that may have provided extra motivation for participants. Previous research has established that regular contact between participant and researcher (Shaw, Fenwick et al. 2011) personal interactions (Zoellner, Powers et al. 2009) social support such as family or friend support, group programmes (Allen and Morey 2010) and social communication in the workplace (Marshall 2004; Lauzon, Chan et al. 2008) can improve adherence to intervention programmes and motivate individuals to increase their physical activity levels. We suggest that frequent participant contact with an onsite researcher during the intervention period is an advantage for discussing step progress and helping them to overcome barriers to physical activity. One intervention (Lauzon, Chan et al. 2008) using pedometers within the workplace reported that on-site meeting increased participants' satisfaction and adherence with pedometer programmes by providing social support such as sharing physical activity progress, identifying pedometer problems and finding solutions, and helping with goal setting. Another study (Aittasalo, Rinne et al. 2012) reported that a single face-to-face contact and monthly email was not sufficient to comply with the intervention programme among office workers in short-term physical activity interventions (6 months).

As participants in the current study were a group of inactive people, the regular contact may have been a positive factor to help them to achieve high levels of physical activity and achieve the measured health benefits. These results are consistent with previous research conducted within workplace settings (Chan, Ryan et al. 2004; Marshall 2004; Thomas and Williams 2006; Ogilvie, Foster et al. 2007) that has identified that employees who start with low physical activity levels have a lower dropout level and a greater recorded increase in physical activity at intervention completion. Other studies have reported only a marginal improvement in step count for employees whose baseline step count indicates they can be classified as physically active (Thomas and Williams

2006; De Cocker, De Bourdeaudhuij et al. 2010; Maruyama, Kimura et al. 2010).

7.6.2 Intervention satisfaction

Participants reported high levels of satisfaction with the programme (median four or five on a 5-point Likert scale) with no difficulty in wearing the pedometer. It was described as useful for providing information about walking as a physical activity for health benefits, self-monitoring and immediate feedback, motivating participants to be more active, and increasing their awareness of physical activity. These positive results are consistent with similar walking studies conducted in a workplace setting (Rooney, Smalley et al. 2003; Thomas and Williams 2006; Gilson, McKenna et al. 2007; Puig-Ribera, McKenna et al. 2008; Maruyama, Kimura et al. 2010; Aittasalo, Rinne et al. 2012).

In the current study, participants reported that the pedometer was useful, very easy to use, and that it was enjoyable to see progress of activity over the duration of the intervention. Similar results have been reported from a study of sedentary employees at five different workplaces (Lauzon, Chan et al. 2008). These results support our findings of a feasible and acceptable intervention when using a pedometer-driven walking programme to increase physical activity and improve health related quality of life in this group and setting. Walking with pedometers has been described as a more convenient means than other physical activities, especially to motivate, and monitor physical activity in sedentary populations (Lauzon, Chan et al. 2008; Tudor-Locke and Lutes 2009) as it can easily provide feedback and an increased personal awareness of physical activity level. This is consistent with our results that have reported that pedometers were very useful and effective in motivating these participants to become more active, providing motivation to change physical activity behaviour in the future.

7.6.3 Physical activity changes

The results of the current study revealed an increase in step count and quality of life scores in the intervention group with slight increases in the control group also noted. The results correspond to approximately 30-40 minutes of increased walking per day. New Zealand physical activity guidelines recommend that every adult accumulate at least 30 minutes of moderate-intensity physical activity on most, if not on all days of the week, in order to obtain health benefits (Ministry of Health 2001). Thus, the recorded increase in activity was sufficient to meet recommended minimum daily levels of physical activity to gain health-related benefits(Ministry of Health 2001).

The increase in step count observed in the current study (3799 steps per day) was more than has been typically reported in the literature for pedometer-based interventions in adults. A review of randomized controlled trials and observational studies of pedometer-based interventions walking interventions (five studies were in workplace settings) in adult populations suggest that on average, pedometer-based interventions result in an increase of approximately 2000 to 2500 steps per day (Bravata, Smith-Spangler et al. 2007). Previous research within workplace populations also reported moderate increase in steps ranging from 445 to 1120 steps per day (Shaw, Alfonso et al. 2007; De Cocker, De Bourdeaudhuij et al. 2010; Maruyama, Kimura et al. 2010; LeCheminant, Smith et al. 2011; Thøgersen-Ntoumani, Loughren et al. 2013). Other studies have observed a non-significant increase of 445 ± 2710 steps per day over four months in office workers (Maruyama, Kimura et al. 2010), a significant decrease in step count after a 20-week intervention at two workplaces (De Cocker, De Bourdeaudhuij et al. 2010), and a minor yet significant increase of 873 steps after four weeks in university employees (Thomas and Williams 2006). However, the current intervention differs from these studies in several ways. These studies had recruited participants with higher levels of physical activity, and methodology and study designs also focused on diet and physical activity.

In contrast other studies have reported greater changes in step count on completion of the intervention when participants have been categorised as low activity. This is consistent with our findings. McDonough et al. (2013) reported an increase of 2776 steps per day after a 12 week walking intervention in a chronic low back pain (CLBP) population, while Chan et al. (2004) reported that steps per day increased from 7,029 at baseline to a plateau of 10,480 (3451 steps per day increase) at the end of the intervention in a sedentary workplace population. Similar results come from a study conducted at 10 worksites in rural New York State (Warren, Maley et al. 2010) that reported an increase of 1506 steps per day after a 10-weeks intervention. All of these studies used pedometers with self-monitoring, regular contact with a facilitator, educational materials, counselling session(s) and goal setting, which are consistent with our intervention, resulting in significant and positive effects for the intervention.

The mean daily increase in step count on completion of the intervention was 3799 steps per day (which is a mean 59% above baseline). This more than favourably compares to an average 26.9% noted in the systematic review of pedometer-based interventions in adult populations (Bravata, Smith-Spangler et al. 2007). These authors suggest that pedometer-based interventions may be more effective at increasing physical activity when participant have a more sedentary lifestyle than those who are already physically active with the argument being that it may be more difficult to accumulate increased steps due to the time constraints of daily living. This is also consistent with a walking systematic review on increasing physical activity (Ogilvie, Foster et al. 2007) that suggests that interventions with sedentary individuals are more successful in increasing physical activity than interventions with physically active individuals.

Our findings support the feasibility of using a pedometer-based intervention in the workplace. The study observed a large effect size (Cohen's d = 1.94) in the intervention group, which is markedly more than that found in a meta-analysis of pedometer-based interventions (Cohen's d=0.8) (Minsoo, Marshall et al. 2009). This effect size was also higher than observed in another systematic review that assessed the increase in daily physical activity based interventions (Cohen's d=0.2) on health-related outcomes in the workplace populations (Conn, Hafdahl et al. 2009). The authors reported that there was a small mean difference between intervention and control groups over the intervention period (MD=612 step per day, all physical activity patterns were transformed to step count). This might be due to a large number of studies included with small effect sizes. It appears that the pedometer-driven behaviour change strategy used in this study (goal-setting and self-monitoring) combined with educational materials, text messages and weekly emails with information on the physical activity benefits, was an effective strategy to promote and improve daily ambulatory activity (i.e. nearly 59% over the 12-week intervention). A recent systematic review and meta-analysis of randomized controlled trials assessing promotion of physical activity within sedentary adults in primary care, demonstrated the positive impact of physician counselling on increasing physical activity levels at 12 months. The majority of the interventions included written materials and advice sessions delivered by professional therapists (Orrow, Kinmonth et al. 2012). In the current study, the use of face-to-face advice session and education materials given by weekly emails and the physical activity booklet are likely to have had a strong effect on increasing step count. Throughout the intervention the researcher made regular visit to the worksite which could have also contributed to motivation and an increase in physical activity over the duration of the intervention.

These components of the intervention were similar to those shown to be successful in increasing physical activity in previous research on pedometer interventions (Chan, Ryan et al. 2004; Bravata, Smith-Spangler et al. 2007; De Cocker, De Bourdeaudhuij et al. 2008). For example, using an individual baseline steps goal to increase steps per day by 5% above previous values each week to reach a 10,000 steps per day target, appears to be feasible in increasing physical activity over the course of the walking programme. This target may have contributed to increased self-efficacy in the intervention group, helping them to increase their overall physical activity over the 12 - week period. It has been proposed in earlier research that use of a common target of 10,000 steps per day can increase the level of physical activity within the intervention (Bravata, Smith-Spangler et al. 2007; Tudor-Locke, Craig et al. 2011). In the current study the increase in daily steps achieved in the intervention group was close to the 10,000 steps per day target which complied with physical activity recommendation for adults to achieve health benefits (Tudor-Locke and Bassett 2004). This indicates that a pedometer walking-based goal of 10,000 steps per day in addition to educational materials was a feasible achievement for low activity meat workers adults to increase their activity over a 12 weeks intervention.

The study also observed a significant intervention effect of improved weekly walking metabolic equivalent minutes (W.MET.min.wk^{-1}) and total weekly metabolic equivalent minutes (T. MET.min.wk^{-1}) including vigorous, moderate, and walking activities. In addition, large effect sizes were observed for those assigned to the intervention group after the initial 12-week intervention period. These data suggest that a higher increase in step-count can confer a greater positive impact in increasing weekly minutes of physical activity as identified in the self-reported results for the International Physical Activity Questionnaire (IPAQ) which is consistent with previous research on physical activity (Chan, Ryan et al. 2004; Faghri, Omokaro et al. 2008; Dishman, DeJoy et al. 2009) within the workplace. In addition, a whole community intervention study (De Cocker, De Bourdeaudhuij et al. 2007) recruited 1242 participants across the East Flanders province of Belgium in 2005 with 68% of the sample being full-time employees. A significant increase in both pedometer and IPAQ self-reported were reported after one year with the majority of participants reporting a positive increase on IPAQ in the workplace setting. The IPAQ data also indicated that the intervention group reduced time spent sitting during the last seven days. This is also consistent with a 6-month pedometer-based intervention among office employees reporting a significant 41 minute decrease in sitting time during a working day (Aittasalo, Rinne et al. 2012).

7.6.4 Health-related quality of life (HRQL)

The results from this study also showed significant improvements in physical component score (PCS) and non-significant improvements in mental component score (MCS) in the pedometer group (increases in SF-36v_2 components); however there were no statistically significant differences between groups observed at 3 months. These improvements are potentially due to an increase in physical activity in this group, and are consistent with findings from other studies (Bize, Johnson et al. 2007; Chan and Tudor-Locke 2008; Harding, Freak-Poli et al. 2013) that reported improvements in HRQL after intervention periods.

Positive associations between increased participation in physical activity and improved health-related quality of life are well published (Conn, Hafdahl et al. 2009; Anokye, Trueman et al. 2012; Fritschi, Brown et al. 2012; Pucci, Rech et al. 2012; Harding, Freak-Poli et al. 2013), highlighting that any increase in daily physical activity can confer wider health benefits. Weight et al. (Weight, Sellon et al. 2013) reported significant ($p<0.001$) improvements in HRQL compared to a control group after a 12-week exercise intervention among physician trainees. The authors concluded that higher levels of physical activity are associated with better HRQL. A recent study by (Harding, Freak-Poli et al. 2013) recruited 487 sedentary employees across a range of workplace settings and assessed the relationship between HRQL and physical activity. At a 4-month follow up MCS scores significantly improved although PCS change was reported as non-significant between groups. Sedentary participants who reported an increased step count had more improvement in MCS than those who did not report an increase in physical activity. These findings are consistent with a recent systematic review of 13 studies including randomized controlled and controlled trials that investigated the effects of pole walking (PW) on HRQL and showed consistent positive associations between PW and HRQL in adults with and without clinical conditions

(Fritschi, Brown et al. 2012). In contrast, Puig-Ribera et al. (Puig-Ribera, McKenna et al. 2008) reported no significant changes in step counts or HRQL as an overall result after a 9-week pedometer-based intervention. However, they observed a significant increase in step count and HRQL in the sedentary participant sub-group, suggesting that participants who were sedentary and/or reported low activity showed greater increases in step counts and HRQL than the moderate and active sup-groups.

7.6.5 Health parameters

In this study, significant improvement in several outcomes, including waist circumference, weight, body mass index, blood pressure, self-efficacy, and body fat was observed after completion of the 12-week intervention, with effect sizes ranging from small to medium. These findings are consistent with previous research that examined the impact of a pedometer-based walking intervention on health-related outcomes within workplace populations (Chan, Ryan et al. 2004; Faghri, Omokaro et al. 2008; Maruyama, Kimura et al. 2010). For example Chan et al.(2004) reported significant decreases in BMI, and waist girth ($p<0.001$ for all) compared to the control (Chan, Ryan et al. 2004). Maruyama et al (2010) reported similar results after 12 weeks, whilst Morgan et al. (2011) observed significant improvements in weight, waist circumference, BMI, and systolic blood pressure compared to the control group at the 14-week follow-up. This is in keeping with several meta-analyses and systematic reviews of walking interventions in adult populations (with or without pedometer) which have reported decreases in body weight, blood pressure, percentage body fat, body mass index and other health-related outcomes after a walking intervention (Proper, Koning et al. 2003; Bravata, Smith-Spangler et al. 2007; Murphy, Nevill et al. 2007; Freak-Poli, Cumpston et al. 2013).

7.6.6 Study limitation

This study has a number of limitations: It was performed on a convenient sample of meat processing workers in a rural population rather than a random sample. Another limitation was the lack of correlation between the outcomes of activity as measured by a pedometer, IPAQ, and 6 min walk test and changes in quality of life, blood pressure, body mass index, body fat percentage, waist circumference, and self-efficacy. A future intervention study with a larger sample size will need to assess these relationships in this population group. Although we evaluated anthropometrical and physiological parameters, our study did not control for eating habits, making it difficult to determine the impacts of intervention on these parameters.

7.7 Conclusions

This study has demonstrated that a 12-week pedometer-based walking intervention in combination with goal setting, and self-monitoring supported by weekly e-mails, was feasible and potentially effective in increasing daily physical activity levels in low active meat workers. The pedometer-based intervention significantly increased physical activity levels and several outcomes, including physical component score, waist circumference, body mass index, self-efficacy, and body fat compared to the control group. Walking is the most popular type of physical activity and is inexpensive and relatively simple to implement in the workplace, demonstrating a high level of adherence and good satisfaction to the intervention. The results indicate that increases in daily physical activity can confer improvements in the other health-related outcomes. More research, in a large randomized controlled trial study with long follow-up, is required to determine the true effectiveness of this intervention in a variety of settings.

8 Chapter Eight

General discussion

This thesis has examined the feasibility of using a pedometer-driven walking intervention to increase physical activity among employees in a New Zealand meat processing workplace. The programme consisted of four components: (goal setting, educational material, self-monitoring and feedback, and social support). The results of this study suggest that these components are a feasible and an effective strategy to promote and improve daily ambulatory activity, at least in the short term. Physical activity provides many health benefits for employees (Schröer, Haupt et al. 2014) and the business and industry sector (Pronk 2009) such as reduced absenteeism and sick leave, as well as increased workplace productivity. Physical inactivity and sedentary lifestyles at work are acknowledged risk factors for many chronic diseases (Kokkinos, Sheriff et al. 2011; Edwardson, Gorely et al. 2012). Increasing the level of physical activity to reduce the burden of chronic diseases and improve health- related quality of life (HRQL) is considered important. Pedometer-based walking interventions are an inexpensive intervention with a low risk of adverse events (Lauzon, Chan et al. 2008), and are becoming widely used as motivational tools to increase the level of physical activity and improve other health-related outcomes in different populations (Bravata, Smith-Spangler et al. 2007).

Several studies have implemented pedometer-driven intervention programmes in the workplace; to our knowledge; this is the first study to examine the feasibility of using a pedometer-driven walking programme among meat processing workers. This study has used an RCT design collecting data at three time points (baseline, at the 12 week conclusion of intervention, and 3 months post-intervention). The literature review (Chapter 4) regarding pedometer-based intervention within workplace setting, found intervention lengths ranged from four weeks (Thomas and Williams 2006) to one year (Gemson, Commisso et al. 2008) with a 12 week median duration. This was considered sufficient duration to determine whether there would be significantly improved health outcomes and increased physical activity behaviours consistent with public health guidelines that aim to achieve 10000 steps per day. Consistent with this, a recent systematic review conducted in a workplace setting (To, Chen et al. 2013) reported that the most successful pedometer-based interventions run for 3-4 months to increase physical activity and improve health outcomes. Furthermore, a meta-analysis of 32 pedometer-based interventions (Kang, Marshall et al. 2009) showed that the effects are moderate to high for studies that lasted between 8 and 15 weeks (ES 0.65, 0.68).

8.1 **Overview of thesis**

There is strong evidence in the literature supporting pedometer-driven interventions improving levels of physical activity ($p<0.001$), BMI ($p=0.03$), blood pressure ($p<0.001$) (Bravata, Smith-Spangler et al. 2007), reducing risk of cardiovascular disease (CVD) in women (Albright and Thompson 2006) and achieving a modest amount of weight loss (Richardson, Newton et al. 2008) in sedentary populations. Despite growth in pedometer driven research studies in the workplace, it remained unclear whether it would be effective in the meat processing setting. In order to understand the nature of the work environment in a meat processing setting, the researcher reviewed the relevant literature in musculoskeletal disorders (MSD) and outlined MSD prevalence in the meat processing industry in Chapter 2. Upon this review, the data highlighted the high frequency of musculoskeletal problems in the workplace setting (Osborne, Blake et al. 2012) and that they were recognized as a highly prevalent disorder in the meat processing industry (Wahl, Gunkel et al. 2000; Silverstein, Viikari-Juntura et al. 2002; van Rijn, Huisstede et al. 2009). The tasks which were performed in the meat processing including: awkward postures, repetitive movements, and heavy physical work were associated with increased incidence of MSDs (Tappin, Bentley et al. 2008; Evangelista, De Fátima Tinoco et al. 2012; Kraatz, Lang et al. 2013). In New Zealand, the incidence rate of injury claims for meat processing was three times higher than for forestry and logging, and the construction industry (Tappin, Bentley et al. 2008). Therefore, MSDs are the primary occupational problem in meat processing in NZ (Tappin, Bentley et al. 2008). Evidence from the literature reported that adults with MSD have an overall poorer health-related quality of life, with decreased daily activities than the general population who report no pain (Gureje, Von Korff et al. 1998; Bergman, Jacobsson et al. 2004; Mäntyselkä, Turunen et al. 2004).

The literature review in Chapter 3 focused on physical activity recommendations, and provided more detail on the benefits of physical activity in the prevention of various chronic diseases. Evidence from the literature reports that participation in physical activities of moderate-intensity, such as walking, is beneficial for people with MSD (Vuori 2001; Proper, Koning et al. 2003; Henchoz and Kai-Lik So 2008; Hendrick, Wake et al. 2010) to decrease pain, disability, and improve physical function and quality of life. Increasing physical activity levels were found to increase or maintain of muscle mass, strength (Karlsson 2004; Kirk, Washburn et al. 2007; Ferreira, Sherrington et al. 2012) and increase bone density (Babatunde, Forsyth et al. 2012) resulting in better quality of life and higher levels of performance in daily activities.

Chapter 3 also explores the validity and reliability of the YAMAX Digiwalker pedometer (DW 200). Several studies have tested the reliability and validity of the DW200, including both free living and laboratory settings with a wide range of populations (Vincent and Sidman 2003; Horvath, Taylor et al. 2007; Feito, Bassett et al. 2012). Various levels of accuracy have been reported for the DW 200 recording error from 1% (Horvath, Taylor et al. 2007; Grant, Dall et al. 2008) to 9% error of actual steps (Hands, Parker et al. 2006). Accuracy depended on the trial instructions, and study populations, but there was a consensus that pedometers are more accurate at walking speeds 60 m.min-1 and above (Le Masurier, Lee et al. 2004; Feito, Bassett et al. 2012), whereas the normal walking speed is accepted as being faster than speeds of 41 $m.min^{-1}$ (Motl, McAuley et al. 2005). In this study, participants were instructed to wear the pedometer on their waist band above the lateral hip during all waking for days and hours of wearing pedometers based on the previous study acceptance protocols (Tudor-Locke, Burkett et al. 2005; Kubota, Nagata et al. 2009). Participants were also asked to walk along a straight 50 metre line to ensure pedometer accuracy which is consistent with the previous studies (Tudor-Locke, Williams et al. 2002; Ryan, Grant et al. 2006; Sugden, Sniehotta et al. 2008) that provided the acceptance criteria of ±2 steps.

An overview of 23 studies using a pedometer-based interventions in the workplace is also presented in Chapter 4, highlighting a number of strengths and weaknesses in the research design and methods of data collection and analysis. The majority of those studies (Gilson, McKenna et al. 2007; Maruyama, Kimura et al. 2010; Ribeiro, Martins et al. 2014) support the utility of pedometers in increasing physical activity and improving other health-related outcomes. This is consistent with the findings of previous systematic reviews (Dugdill, Brettle et al. 2008; To, Chen et al. 2013), which found an improvement in physical activity levels, and suggested that the workplace interventions that used a pedometer can increase daily step counts and positively impact upon physical activity behaviour. However, despite the reported positive changes in physical activity levels, there were some limitations including the lack of control groups, which makes it difficult to conclude that improvements observed in those studies were attributable to participation in the intervention programme. Randomized controlled trials provide the best level of evidence on intervention effects and increase study validity because the differences between the intervention and control group can be easily attributed to the intervention programmes (Slavin 1995; Barton 2000). Furthermore, most studies were also pre-post-test and quasi-experimental in design, based in the workplace, and thus may have primarily recruited already active participants. A systematic review by (Ogilvie, Foster et al. 2007) suggests that walking-based interventions with sedentary individuals are more likely to be successful at increasing physical activity than those with physically active individuals. In order to better identify the effects of a pedometer-based intervention, further studies are required in the workplace with a randomized controlled design.

The objective of Chapter 5 was to use a systematic review design in order to investigate the strength of evidence for pedometer-driven walking interventions for patients with MSD. This included randomized controlled trials (RCT) and controlled trials without randomization published in the English language, which examined the effects of a pedometer-based walking intervention to increase physical activity levels and improve health-related outcomes in patients with MSD. This review was completed on 20 February 2014. Seven studies were included, allowing data extraction on 484 participants with an age range of 40 to 82 years. Interventions lasted from 4 weeks to 12 months and the results across studies showed significant increases in step count ($p < 0.05$) following the intervention. Across these studies, there was a mean increase in physical activity of 1950 steps per day relative to baseline. Improvements in physical function and pain scores were also noted in these study populations. This review provides strong evidence for the effectiveness of pedometer-based interventions in increasing physical activity among patients with MDS in the short-term. Qiu and colleagues similarly presented moderate evidence for pedometer based walking interventions playing a role in improvement in glycaemic control among patients with type 2 diabetes (Qiu, Cai et al. 2014). They reported a significant increase of 1822 steps per day (95% CI, 751 to 2894 steps per day) over the intervention period. The systematic review by Bravata and colleagues also reported an increase of 2500 steps per day not only in the general population, but also in those with chronic diseases such as arthritis, diabetes, and obesity (Bravata, Smith-Spangler et al. 2007). Our findings suggest that a combination of interventions is likely to be the most effective strategy in increasing physical activity and maximizing health benefits. This finding is reflective of evidence from previous systematic reviews suggesting that combining pedometer-driven walking programmes with goal setting is more effective than pedometer-driven walking alone in adult populations (Bravata, Smith-Spangler et al. 2007; Qiu, Cai et al. 2014). However, variation in methodology, outcome measures, statistical methods and study subjects amongst the reviewed studies precluded a formal meta-analysis. Future research with higher methodological quality and larger sample sizes is needed to investigate the effectiveness of pedometer-driven walking for improving physical activity and health-related outcomes in MSDs. The results of this study have been submitted for publication in the BMC Musculoskeletal Disorders journal.

Based on the results of the reviews from Chapters 2 to 5, the importance of physical activity is supported in the prevention and management of various chronic diseases as well as in the improvement of quality of life in workplace populations (Dugdill, Brettle et al. 2008; Conn, Hafdahl et al. 2009). Pedometers have been widely used as a motivational strategy and intervention to promote physical activity levels, and improve health status (Bravata, Smith-Spangler et al. 2007; Kang, Marshall et al. 2009). Our review provides the theoretical framework, and rationale for pedometer-based interventions through the use of written health materials, goal setting and regular contact, which may deliver positive effects for increased habitual physical activity and health outcomes in the short-term. The design was thus based on self-regulation theory and methodologies of the main study are described in Chapter 6. This chapter outlines a study to evaluate the feasibility and acceptability of using a pedometer-based intervention programme to promote physical activity among meat processing workers at 12- and 24-week follow-up points. This includes a description of aims, hypothesis, description and selection criteria of participants, randomization, measurement process, intervention protocol, and data collection protocol and statistical analyses used to detect the variance and effect size using standardised effect sizes (Cohen d values): 0.2 for small effect, 0.5 for medium effect, and more than 0.8 for large effect (Cohen 1988). The methodology for this research has been previously published (Mansi, Milosavljevic et al. 2013).

A feasibility study was conducted to provide information on procedures, and to provide data for the feasibility and effect size for the main RCT in the future. The results (Chapter 7) found a high level of adherence (93.1%) to the pedometer intervention programme and 90% for the control group. There was a significant increase in mean step count from 5993 steps per day during week 0 (baseline) to 9792 steps per day by week 12 post-trial ($p < 0.005$, 95% CI, 9011 to 10573) or an absolute increase of 3799 ± 2053 steps per day as well as a large effect size between groups (ES =1.94). These findings provide strong evidence that the workplace setting is an optimal setting for increasing the level of physical activity and health promotion among sedentary employees for at least the short term. Findings from several previous reviews provide mixed findings. Some provide insufficient evidence that workplace physical activity based interventions are not effective (Dishman, Oldenburg et al. 1998; Marshall 2004). In contrast, others found evidence of beneficial effects of workplace interventions on increasing the levels of physical activity and improving other health outcomes (Proper, Koning et al. 2003; Dugdill, Brettle et al. 2008; Malik, Blake et al. 2013; To, Chen et al. 2013; Schröer, Haupt et al. 2014). The authors suggest that using high quality randomised controlled trial interventions with different behaviour strategies is an effective strategy to increase physical activity and improve health status.
The results also showed improvements in the level of quality of life in the pedometer group, and a significant intervention effect for weekly walking metabolic equivalent minutes (W.MET.min.wk^{-1}) and total weekly metabolic equivalent minutes (T. MET.min.wk^{-1}) $p < 0.005$, and $p < 0.005$ respectively. These findings are consistent with a recent systematic review that investigated the effects of walking interventions on health-related quality of life and showed consistent positive associations between walking interventions and a variety of health-related quality of life outcomes in adults with and without clinical conditions (Fritschi, Brown et al. 2012). Participants also showed improvements in several secondary outcomes, including waist circumference, weight, body mass index, blood pressure, self-efficacy, and body fat at the 12-week

intervention completion, with effect sizes ranging between small to medium. These findings are consistent with previous systematic reviews targeting different populations, including occupational populations (Freak-Poli, Cumpston et al. 2013; To, Chen et al. 2013), type 2 diabetes (Funk and Laurette Taylor 2013), overweight and obese women (Richardson, Newton et al. 2008; Nascimento, Pudwell et al. 2014), and general populations (Bravata, Smith-Spangler et al. 2007)that demonstrate positive effects for a range of pedometer walking interventions to increase physical activity levels and improve a wide range of health outcomes. These results support the feasibility and acceptability of using a pedometer-driven walking intervention programme to increase physical activity and improve health related quality of life in workplace settings.

8.2 Methodological considerations

The pedometer-based intervention was implemented within the workplace setting to gather and analyse data on physical activity and other health outcomes. Fifty-eight people (24 male and 34 female) participated in the current study, which took place at a meat processing plant in the South Island of New Zealand. Based on the results from review Chapters 2-5, it appeared that the meat industry setting lacked physical activity interventions. The fundamental notion was to employ a very simple walking intervention protocol, without any challenges for the participants or the worksite itself. Walking with pedometers is generally acceptable to participants with little risk of adverse events (Tudor-Locke and Lutes 2009). The choosing of sedentary participants in the current study aims at reducing or minimizing participants impact on their health care system (Heath, Parra et al. 2012) and to change their physical activity behaviour (Ogilvie, Foster et al. 2007) to allow them become more active. Based on the literature chapters (Chapters 2-5), we decided to use pedometer-based interventions with goal setting, educational material, self-monitoring and feedback, and social support for their ease to employ and adherence to the programme. Further information and explanations on the methodology are discussed below.

8.2.1 Characteristics of participants

Demographic characteristics of the sampled meatworkers demonstrate that the majority of participants were female (58.6%). This is consistent with the findings of previous intervention studies (Rooney, Smalley et al. 2003; VanWormer, Pronk et al. 2006; Lauzon, Chan et al. 2008), which found that the majority of participants were female and suggest that females are more likely to participate in physical activity interventions than males. Epidemiological evidence indicates that participation rates among women in scientific studies were higher than men (Dunn, Jordan et al. 2004; Galea and Tracy 2007). This may be due to poorer levels of health status among females worldwide (Oguma, Sesso et al. 2002), although female participation is more likely in aerobic activities such as walking than vigorous in kinds of activities (Oguma, Sesso et al. 2002; Kilpatrick, Hebert et al. 2005). Apparently, women's greater participation in physical activity is to increase the level of activity towards improving their health status especially in weight loss studies (Kilpatrick, Hebert et al. 2005).

8.2.2 Intervention components

Extensive research has been conducted on physical activity-based interventions. Accepting that physical activity is a "behaviour" intervention, participation in physical activity intervention research could help participants change their behaviour (beliefs, and attitudes) towards being more active (Marcus and Forsyth 2009). Pedometer-based interventions using the self-regulation theory strategies, with goal setting, educational materials, feedback and social support for promoting physical activity, have been found to be effective in increasing the levels of physical activity within a wide range of settings (Baumeister, Gailliot et al. 2006; Conn, Hafdahl et al. 2008; Dombrowski, Sniehotta et al. 2012). The following paragraphs are brief summaries of the intervention components.

8.2.2.1 Goal setting and 10,000 steps recommendation

Research has identified that regular participation in physical activity is known to have important benefits for reducing general risk of premature mortality across all groups (Wen, Wai et al. 2011; Gulsvik, Thelle et al. 2012). International guidelines have recommended that every adult accumulate at least 150 minutes of moderate-to-vigorous intensity physical activity weekly (World Health Organisation 2011)or walk a minimum of 10,000 steps per day to improve health and well-being (Hatano 1993; Tudor-Locke and Bassett 2004). The value of 10,000 steps per day was originally established in Japan and remains widely familiar to all populations today (Tudor-Locke and Bassett 2004). However, all participants in this study accumulated less than 7,499 steps per day at baseline which classified them as low active and/or sedentary based on proposed indices of pedometer-determined physical activity (see Table 25).

Table 25: Activity classification for pedometer step counts in healthy adults

Category	Steps per day
Sedentary	< 5000
Low active	5000-7499
Somewhat active	7500-9999
Active	10,000-12499
Very active	>12,500

Source: Based on values from(Tudor-Locke and Bassett 2004)

Sedentary population should start with small amounts of activity and gradually increase their activity levels over time (Peterson 2007). The results reported an increase of 3799 steps per day over the 12-week intervention, equivalent to an extra 30-40 minutes walking per day, or an extra 150 kcal energy per day (Tudor-Locke, Sisson et al. 2005; Choi, Pak et al. 2007). This is consistent with current public health recommendations to increase physical activity to at least 150 min per week (World Health Organization 2011). Participants were asked to increase their activity gradually by 5% above their previous goal setting target and attempt to reach at least 10,000 steps per day at the end of the intervention. Strong evidence shows that using personalized step-count goals were better than using other techniques to promote physical activity behaviour (Bravata, Smith-Spangler et al. 2007; Qiu, Cai et al. 2014). Furthermore, pedometer-based interventions that incorporate the 10,000 steps per day goal setting into the programme were the most effective strategy in increasing physical activity, with the highest effect size (ES = 0.84, 95% CI = 0.43, 1.24) for adults (Kang, Marshall et al. 2009).

The target of 10,000 steps was approximately achieved by the majority of participants with a mean of 9792 steps per day, consistent with previous studies using a 10,000 step recommendation that have shown that when daily step count significantly increased, there was a range of significant clinical health benefits in sedentary populations (Brown, Eakin et al. 2003; Sidman, Corbin et al. 2004; Brown, Mummery et al. 2006; Schneider, Bassett Jr et al. 2006; Bravata, Smith-Spangler et al. 2007)and interventions conducted within workplace populations (Rooney, Smalley et al. 2003; Thomas and Williams 2006; VanWormer, Pronk et al. 2006; De Cocker, De Bourdeaudhuij et al.

2007; Gilson, McKenna et al. 2007; Musto, Jacobs et al. 2010; Samuels, Raedeke et al. 2011).

The results of the current study show a significantly greater increase in step count from baseline to end of intervention compared to university employees (2,783 steps per day) (Samuels, Raedeke et al. 2011) and an East Flanders provincial population (896 steps) (De Cocker, De Bourdeaudhuij et al. 2007). Overweight/obese sedentary adults increased their step count by a similar amount (3994 steps) over a 36-week intervention (Schneider, Bassett Jr et al. 2006). Table 26 shows that in each study that used a target of 10,000 steps reinforce the notion that the 10,000 target is a useful behavioural target for increasing physical activity. It is important to note that the results of the current study support the previous finding that sedentary population with low baseline step counts are more likely to meet the 10,000 steps physical activity recommendations, with a strong positive association between meeting the 10,000 step goal and improvements in health-related parameters (Tudor-Locke and Bassett 2004; Speck, Hill et al. 2010).

Table 26: Average daily step increases from the daily 10,000 step goal

Studies	Baseline step-count	Daily step goal	Post-step-count		p-value
(Schneider, et al. 2006)	5123	10,000	9117	3994	p = 0.05
(Samuels, et al. 2011)	6320	10,000	9103	2,783	p=0.05
(Musto, et al. 2010)	4244	10,000	9889	5646	P < .001
(Gilson, et al. 2007)	8290	10,000	9287	997	p< 0.002
(De Cocker, et al. 2007)	9596		10,491	896	p=.001
(Thomas and Williams 2006)	8501	10,000	9374	873	N/A
(VanWormer, et al. 2006)	8800	10,000	9963	1,163	P < 0.001

Walking 10,000 steps per day is accepted as likely to improve health parameters (Tudor-Locke, Craig et al. 2011). In the present study, improvements in blood pressure (BP), body mass index (BMI), body fat percentage (BF), waist circumference (WC), self-efficacy, and body weight were reported. This is consistent with other workplace pedometer- based interventions that report a reduction in body weight, BMI, WC (Schneider, Bassett Jr et al. 2006; Musto, Jacobs et al. 2010), and blood pressure (Iwane, Arita et al. 2000).These results are also consistent with research that has found moderate intensity physical activity such as walking activity may be a greater motivator to a sedentary population than high-intensity physical activity for enhancing activity levels (Ekkekakis and Petruzzello 1999; Williams, Dunsiger et al. 2008) and improving health outcomes. This is consistent with a recent review (De Feo 2013) that has concluded that sedentary obese persons had low self-efficacy, and were not familiar with high-intensity physical activity before starting the intervention programme. The authors suggest that regular moderate intensity is the optimal mode of intensity to keep sedentary participants in the intervention programmes and motivate them to get positive results (De Feo 2013), whereas sedentary individuals prefer to select an exercise at moderate intensities to increase their activity (Piana, Battistini et al. 2013).

8.2.2.2 Social support

There are different techniques used to help people increase their physical activity levels in the literature. Pedometer-based interventions with a combination of behavioural support materials have been widely used in workplace settings (Chan, Ryan et al. 2004; Miller and Brown 2004) and other populations (Brown, Mummery et al. 2006; Vallance, Courneya et al. 2007; De Cocker, De Bourdeaudhuij et al. 2008). The purpose of behavioural support materials is to provide knowledge regarding health benefits of physical activity, and to motivate individuals to improve and change their physical activity behaviour both during and after the intervention (Robison and Rogers 1994).

The results indicate that the majority of participants utilised the behavioural support materials that were provided over 12 weeks by an email message and physical activity booklet (Table 19). This is consistent with evidence from numerous systematic reviews of physical activity interventions that have concluded that behavioural support materials will have a positive effect on increasing the amount of physical activity

(Kahn, Ramsey et al. 2002; Bravata, Smith-Spangler et al. 2007; Ogilvie, Foster et al. 2007; Malik, Blake et al. 2013) at least in the short term. Other evidence has also concluded that pedometer-based interventions in combination with different behavioural approaches were more effective at increasing walking behaviour (Bravata, Smith-Spangler et al. 2007; Ogilvie, Foster et al. 2007; Kang, Marshall et al. 2009; Qiu, Cai et al. 2014) and may provide a larger increase in activity than pedometer alone. Participants received weekly emails about physical activity benefits which may have increased awareness of daily activity levels necessary to achieve their step targets, and hence increased adherence to regular physical activity resulting in increasing levels of physical activity. Recent reviews (Latimer, Brawley et al. 2010; Gallagher and Updegraff 2012; Malik, Blake et al. 2013; To, Chen et al. 2013) indicate that individuals' beliefs about physical activity can be affected by messages, including the benefits of being active, and ways to be active, and may increase the level of physical activity (Bravata, Smith-Spangler et al. 2007; Gilson, McKenna et al. 2007; Malik, Blake et al. 2013; Ribeiro, Martins et al. 2014).

8.2.2.3 Feedback and self-monitoring

Pedometers provide immediate and continuous feedback on the number of daily steps taken for the users and the majority of participants reported that the pedometer was effective in increasing their activity. This finding is consistent with a review that investigated pedometer intervention characteristics for increasing physical activity, advocating use of self-monitoring pedometers to provide feedback and information to promote lifetime activity (Tudor-Locke and Lutes 2009). Data from a meta-analysis investigating the effectiveness of pedometer interventions also demonstrate that participants who receive pedometer feedback and record their step count significantly increase their steps by 2000 to 3200 steps compared to a non-recorded step group (Bravata, Smith-Spangler et al. 2007). The authors concluded that using a combination strategy, such as goal setting with self-monitoring feedback appeared to be a successful approach to increasing physical activity in the general population for the short-term. A number of studies show that pedometer self-monitoring may have positive short-term effects on activity levels both within the workplace setting (Chan, Ryan et al. 2004; Thomas and Williams 2006; Lauzon, Chan et al. 2008; Aittasalo, Rinne et al. 2012) and in general populations (Bravata, Smith-Spangler et al. 2007). However, when participants have reported their step count every day on the daily record, this also provides additional feedback on their physical activity progress over the course of the intervention.

8.3 **Validity of outcome measures**

Daily physical activity is defined as "*any bodily movement produced by the skeletal muscle that results in energy expenditure*" (Caspersen, Powell et al. 1985). In order to evaluate the current and changing physical activity levels, accurate assessment of physical activity levels is required. In this study, the researcher used the DW200 pedometer DW200 (Yamax, Tokyo, Japan) and the IPAQ-short form to evaluate habitual physical activity over each measurement time point, which represent both objective and subjective methods. The majority of studies have used one study arm at the same time to provide physical activity data. In the literature, there are consistent results from various literature reviews for physical activity obtained by objective and subjective measurements (Craig, Marshall et al. 2003; Van Der Ploeg, Tudor-Locke et al. 2010; Kim, Park et al. 2013). Authors concluded that the IPAQ shows moderate correlation between reported and objective tools (pedometers, accelerometers, and fitness measures), which supports the use of the IPAQ to monitor adults in diverse settings. In contrast, another systematic review (Lee, Macfarlane et al. 2011) indicated only weak evidence for the ability of the IPAQ-SF to assess physical activity correctly, reporting 84% overestimation of physical activity. Another systematic review and meta-analysis (Prince, Adamo et al. 2008) identified that the self-report questionnaire was less accurate than the pedometer, and reported higher levels of self-reported physical activity when compared to the pedometer results. Although the IPAQ is less accurate in the measurement of physical activity, it is the most commonly used tool to assess physical activity because it is low-cost, easily completed within 5 minute, and generally accepted in the general population (Craig, Marshall et al. 2003).

Objective methods such as pedometers offer more accurate estimates of physical activity and eliminate many of the deficiencies in the self-report questionnaire (Prince, Adamo et al. 2008). The DW200 has been widely used in different populations to evaluate the accuracy of step counts under different conditions and populations. This pedometer is a valid and reliable tool for counting steps in adults under free living conditions (Vincent and Sidman 2003; Kang, Bassett et al. 2012), all weight categories (Tyo, Fitzhugh et al. 2011), laboratory conditions (Le Masurier and Tudor-locke 2003;

Motl, McAuley et al. 2005; Grant, Dall et al. 2008) and different pedometer positions (Horvath, Taylor et al. 2007). It was found to be the most accurate pedometer in counting steps, recording between 1-3% error within both free living and controlled laboratory settings (Le Masurier, Lee et al. 2004; Feito, Bassett et al. 2012). However, there are some limitations as this model has a spring-levered arm, which moves up and down to register movements in the vertical accelerations during activity (Tudor-Locke, Williams et al. 2002; Vanhees, Lefevre et al. 2005). This feature was unable to measure some activities correctly such as upper body activity during jogging or running, swimming, cycling, and carrying loads (Tudor-Locke, Williams et al. 2002; Tudor-Locke and Lutes 2009).

In this study we also used the SF-36v2 as a tool to measure health-related quality of life (HRQL). The SF-36v2 questionnaire is self-administered, and provides a generic health status that measures HRQL within eight sub-scales, each examining a different dimension of health: physical functioning, physical role, bodily pain, general health, vitality, social functioning, emotional role, and mental health (Ware Jr and Sherbourne 1992). It has been shown to have very good psychometric properties, with high internal consistency and test-retest reliability values in various studies with a range of ages and health conditions (Taft, Karlsson et al. 2004; Morfeld, Bullinger et al. 2005; Motamed, Ayatollahi et al. 2005; ten Klooster, Vonkeman et al. 2013; Thumboo, Wu et al. 2013; Stull, Wasiak et al. 2014). While the designs, methodologies and patient/population samples of these studies have been at considerable variance, the SF-36v2 questionnaire appears to be a consistently reliable and valid tool for the assessment of health-related quality of life in the general population and population with chronic conditions (Laguardia, Campos et al. 2011; Thumboo, Wu et al. 2013; Stull, Wasiak et al. 2014). The SF-36v2 is now one of the most well used measures of health and quality of life in survey and clinical research.

8.4 Study limitations, strengths, and future research directions

As this is a feasibility study, there are limitations to the study that should be addressed in a full RCT in future. It was performed on a convenience sample of predominantly female subjects at a work site in a rural population. Therefore, these results may not be representative of an entire population and should not be generalized to all meat workers in New Zealand. Future RCT studies are needed to compare different sites with larger sample sizes. In addition, participants were not blinded to allocation of the intervention, and also were able to monitor daily pedometer step counts throughout the seven day assessment periods. The non-concealment of the pedometer may have influenced step-count levels in both groups at assessment points. Another limitation relates to the SF-36 self-reported questionnaire: it has a multidimensional component that is influenced by many factors, which may influence the respondent's behaviour and recall bias, which may have affected the accuracy of results.

This study has several strengths; firstly, this is the first pedometer-based intervention, to our knowledge, conducted in New Zealand among meat processing workers. Therefore, the information and data on step count and other health parameters will provide direction for future pedometer intervention studies in a diverse setting to avoid methodological limitations. Secondly, we used a pedometer and IPAQ-short form to evaluate habitual physical activity at baseline and at follow-ups, which represent objective and subjective methods. We also chose the most accurate pedometer available on the market based on clinical studies. This pedometer is a valid and reliable tool for counting steps in adults under free living condition (Vincent and Sidman 2003; Kang, Bassett et al. 2012). Providing data regarding physical activity by using both subjective and objective methods provides accurate data for future studies. Thirdly, we highlighted the high frequency of musculoskeletal problems in the workplace setting and provided details regarding the risk factors that contribute to the occurrence of MSD in the workplace setting. Finally, in the present study participants received information on the benefits of physical activity, individual goal setting, and social support. This approach was effective in increasing physical activity and other health outcomes in the short-term. Therefore, future pedometer-based intervention studies with longer follow-up and a larger sample size are needed to assess long-term physical activity changes and adherence.

8.5 **Practical applications**

Consistent with a number of previous studies using pedometers as intervention tools to increase physical activity within workplace populations, this research had a goal of achieving at least 10,000 steps per day. It is considered to be an important factor to meet physical activity guidelines and hence confer health benefits.

The results from this thesis show that the intervention reported a large effect size in increasing physical activity with significant improvements in other health outcomes. Therefore, use of a simple, cheap, pedometer-driven walking intervention, incorporating goal setting, feedback, educational material, and self-monitoring can be integrated into the primary care setting. It is proposed that pedometers can be applied by a variety of health professionals and become part of routine care towards improving the health and lifestyle of patients in the primary care setting. This study provides a link between increased physical activity and improved health status and is considered to be a potentially useful strategy for health care professionals who are treating patients with hypertension and weight loss. The programme is simple, does not need sophisticated equipment, is low cost and thus could be implemented in clinics and in primary health care settings.

8.6 Conclusions

This thesis has demonstrated that a pedometer-driven walking intervention is feasible and effective in increasing step count within the workplace setting (meat processing populations) over the short term. A pedometer-based intervention significantly increased physical activity levels (step count) compared to the control group. Participants reported a high rate of adherence and retention to the walking programme over the intervention period. Significant improvements in physical component score (PCS) and non-significant improvements in mental component score (MCS) were observed in the pedometer group. Importantly the pedometer based intervention improved several secondary health outcomes, including waist circumference, weight, body mass index, blood pressure, self-efficacy, and body fat after completion of the 12-week intervention. The effect size of this intervention, in this sampled population was significant and considerable and the research design is considered to be easily reproducible and feasible. Further research is planned for larger sampled RCTs within the workforce across a multitude of worksites in New Zealand. In the interim these significant results strongly contribute to the evidence supporting increased moderate amounts of physical activity as being effective strategies for improvement in health status within a workforce. Therefore, future pedometer-based intervention studies with longer follow-up and a larger sample size are needed to assess long-term physical activity changes and adherence.

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Appendices

Appendix 1:University of Otago Human Ethics Committee Approval

12/313

UNIVERSITY OF OTAGO
NEW ZEALAND

Academic Services
Manager, Academic Committees, Mr Gary Witte

25 January 2013

Assoc. Prof. S Milosavljevic
School of Physiotherapy

Dear Assoc. Prof. Milosavljevic,

I am again writing to you concerning your proposal entitled "**Feasibility of using pedometer-driven walking to promote physical activity and improve health-related quality of life among meat-processing workers: a randomized controlled trial**", Ethics Committee reference number **12/313**.

Thank you for your email of 23/01/13 which provided a copy of the letter of approval for your research to be conducted onsite at Silver Fern Farms Finegand; a copy of the advertisement that will be used; and your amended Information Sheet. We confirm that these documents are approved.

On the basis of this response, I am pleased to confirm that the proposal now has full ethical approval to proceed.

Approval is for up to three years from the date of this letter. If this project has not been completed within three years from the date of this letter, re-approval must be requested. If the nature, consent, location, procedures or personnel of your approved application change, please advise me in writing.

Yours sincerely,

Mr Gary Witte
Manager, Academic Committees
Tel: 479 8256
Email: gary.witte@otago.ac.nz

c.c. Professor G D Baxter Dean School of Physiotherapy

Appendix 2: Consultation with Maori

NGĀI TAHU RESEARCH CONSULTATION COMMITTEE
TE KOMITI RAKAHAU KI KĀI TAHU

Tuesday, 18 December 2012.

Associate Professor Stephen Milosavljevic,
School of Physiotherapy,
DUNEDIN.

Tēnā Koe Associate Professor Stephen Milosavljevic,

Feasibility of using pedometer-driven walking to promote physical activity and improve health-related quality of life among meat processing workers: a randomized controlled trial.

The Ngāi Tahu Research Consultation Committee (The Committee) met on Tuesday, 18 December 2012 to discuss your research proposition.

By way of introduction, this response from The Committee is provided as part of the Memorandum of Understanding between Te Rūnanga o Ngāi Tahu and the University. In the statement of principles of the memorandum it states "Ngāi Tahu acknowledges that the consultation process outline in this policy provides no power of veto by Ngāi Tahu to research undertaken at the University of Otago". As such, this response is not "approval" or "mandate" for the research, rather it is a mandated response from a Ngāi Tahu appointed committee. This process is part of a number of requirements for researchers to undertake and does not cover other issues relating to ethics, including methodology they are separate requirements with other committees, for example the Human Ethics Committee, etc.

Within the context of the Policy for Research Consultation with Māori, the Committee base consultation on that defined by Justice McGechan:

"Consultation does not mean negotiation or agreement. It means: setting out a proposal not fully decided upon; adequately informing a party about relevant information upon which the proposal is based; listening to what the others have to say with an open mind (in that there is room to be persuaded against the proposal); undertaking that task in a genuine and not cosmetic manner. Reaching a decision that may or may not alter the original proposal."

The Committee considers the research to be of importance to Māori health.

As this study involves human participants, the Committee strongly encourage that ethnicity data be collected as part of the research project. That is the questions on self-identified ethnicity and descent, these questions are contained in the 2006 census.

The Committee suggests including in the research team a researcher with expertise in analysing and interpreting data by ethnicity.

The Committee suggests dissemination of the findings to relevant Māori health organisations.

We wish you every success in your research and The Committee also requests a copy of the research findings.

The Ngāi Tahu Research Consultation Committee has membership from:

Te Rūnanga o Ōtākou Incorporated

NGĀI TAHU RESEARCH CONSULTATION COMMITTEE
TE KOMITI RAKAHAU KI KĀI TAHU

This letter of suggestion, recommendation and advice is current for an 18 month period from Tuesday, 18 December 2012 to 18 June 2014.

Nāhaku noa, nā

pp NTRCC

Mark Brunton
Kaiwhakahaere Rangahau Māori
Research Manager Māori
Research Division
Te Whare Wānanga o Otāgo
Ph: +64 3 479 8738
Email: mark.brunton@otago.ac.nz
Web: www.otago.ac.nz

The Ngāi Tahu Research Consultation Committee has membership from:
Te Rūnanga o Ōtākou Incorporated

Appendix 3.: Consent form

[Reference Number *as allocated upon approval by the Ethics Committee*]
[*April 2011*]

UNIVERSITY of OTAGO
Te Whare Wānanga o Otāgo
NEW ZEALAND

Feasibility of using pedometer-driven walking to promote physical activity, and improve health-related quality of life among meat processing workers: randomized controlled trial.

CONSENT FORM FOR PARTICIPANTS

I confirm that I have received and read the details of the research project being undertaken from December 2012 and understand the purpose for which this data is being collected. All my questions have been answered to my satisfaction. I understand that I am free to request further information at any stage.

I know that:-

1. My participation in the project is entirely voluntary;

2. I am free to withdraw from the project at any time without any disadvantage;

3. Personal identifying information [age, sex, height, marital status, education, and employment status] will be destroyed at the conclusion of the project but any raw data on which the results of the project depend will be retained in secure storage for at least five years;

4. The results of the project may be published and will be available in the University of Otago Library (Dunedin, New Zealand) but every attempt will be made to preserve my anonymity.

I agree to take part in this project.

(Signature of participant) (Date)

This study has been approved by the University of Otago Human Ethics Committee. If you have any concerns about the ethical conduct of the research you may contact the Committee through the Human Ethics Committee Administrator (ph 03 479 8256). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.

Appendix 4: Advertisement poster

UNIVERSITY of OTAGO
Te Whare Wānanga o Otāgo
NEW ZEALAND

Physical activity and well- being

The school of Physiotherapy at Otago University is investigating whether a pedometer-driven walking program can improve health-related quality of life, and increase physical activity in a population of meat processing workers.

We are looking for males and females aged between 18 to 65, who exercise for less than 30 min 3 days/week

Participants will be required to complete 2 questionnaires which may take approximately 20 min, and also ask you to wear a pedometer for a 24 week period during all waking hours, and also need to complete a blood pressure, body fat, waist circumference, height, weight, and a six minute walk tests.

If you are interested in participating or would like more information please contact: Suliman Email: **almsu521@student.otago.ac.nz or 0226087643**

This project has been reviewed and approved by the University of Otago Human Ethics Committee (Ref 12/313)

Physical activity and well-being almsu521@student.otago.ac.nz **or**	Physical activity and well-being almsu521@student.otago.ac.nz **or** 0226087643	Physical activity and well-being almsu521@student.otago.ac.nz **or** 0226087643	Physical activity and well-being almsu521@student.otago.ac.nz **or** 0226087643	Physical activity and well-being almsu521@student.otago.ac.nz **or** 0226087643	Physical activity and well-being almsu521@student.otago.ac.nz **or** 0226087643	Physical activity and well-being almsu521@student.otago.ac.nz **or** 0226087643	Physical activity and well-being almsu521@student.otago.ac.nz **or** 0226087643	Physical activity and well-being almsu521@student.otago.ac.nz **or** 0226087643	Physical activity and well-being almsu521@student.otago.ac.nz **or** 0226087643

Appendix 5: Information sheet for participants

[Reference Number *as allocated upon approval by the Ethics Committee: April 2011*]

Feasibility of using pedometer-driven walking to promote physical activity, and improve health-related quality of life among meat processing workers: randomized controlled trial.

INFORMATION SHEET FOR PARTICIPANTS

Dear Volunteer,

Thank you for your interest in this project. This information is designed to explain the purpose of this project to you. Please read this information sheet carefully before deciding whether or not to participate. If you decide to participate we thank you. If you decide not to take part there will be no disadvantage to you of any kind and we thank you for considering our request.

What is the Aim of the Project?

The aim of this study is to assess the feasibility of whether a pedometer driven walking program can improve health status and increase physical activity levels in meat processing workers.

What Type of Participants are being sought?

We are looking for males and females aged between 18 to 65, who exercise for less than 30 min 3 days/week. Participants who agree to take part in this study will receive $20 in appreciation for their time at the completion of the study

What will Participants be Asked to Do?

After successfully completing the baseline assessment and signing the informed consent, eligible participants will be assigned to one of two groups, a pedometer-driven walking group (intervention) or a normal lifestyle group (control). All potential participants will be instructed to wear a pedometer for 7 days in order to establish baseline step-counts during normal daily activity, prior to the start of the 12 week intervention programme.

Participants will be surveyed at regular intervals (baseline, 12-week, and 24-week) to provide information about health-related quality of life, and physical activity levels. The survey will take about 20 minutes to complete. In addition measurements of blood pressure, body fat, waist circumference, height, weight, and a six minute walk tests will also be taken at the same time points. Furthermore, participants in both the intervention (pedometer-walking programme) and control groups will also receive standardised educational material that consists of written and graphic information describing the importance of walking as a physical activity for health benefits and prevention of different diseases. During the following 12 weeks, participants in the intervention group (pedometer-walking program) will be asked to wear a pedometer during all waking hours, except when bathing, swimming or going to bed at night. You will also be given a step calendar to record your walks and note per day as to whether you are applying the program or not, the time of day, duration of the walk, the week's step-count goal, and the total number of steps displayed on the pedometer at the end of each day. You will also receive weekly e-mail reminders about your weekly step-count goal in order to reach at least 10,000 steps/day at the end of the 12 week period. The control group will be encouraged to read the educational activity material and be asked to record any exercise they perform during this period. At the completion of the 12 weeks both groups will again use the pedometer for 7 days to establish a weekly step count for comparison to baseline scores. This will also take place at a 6 month time point from initial baseline measurement.

What Data or Information will be Collected and What Use will be Made of it?

We will be collecting personal information from you including your age, sex, ethnicity, address, height, weight, education, and work position. During the course of the study, we will also be collecting the results of the outcome measurements stated above, such as blood pressure, waist circumference etc. The data collected will be securely stored in such a way that only those involved in the project will be able to gain access to it, but data will in no way be linked to any specific participant. At the end of the project any personal information will be destroyed immediately except that, as required by the University's research policy, any raw data on which the results of the project depend will be retained in secure storage for five years, after which it will be destroyed. The results of the project may be published and will be available in the University of Otago Library (Dunedin, New Zealand) but every attempt will be made to preserve your anonymity. The results of this study will eventually be used to develop the main project.

Can Participants Change their Mind and Withdraw from the Project?

Should you feel the need to withdraw from the project, you may do so without question at any time. You may withdraw from participation in the project without any disadvantage to yourself of any kind.

What if Participants have any Questions?

If you have any questions about our project, either now or in the future, please feel free to contact either:-

Suliman Almansi **or** **Prof David Baxter**

School of Physiotherapy
Telephone Number: (03) 479 9619

School of Physiotherapy
Phone Number: (03) 479 7411

This study has been approved by the University of Otago Human Ethics Committee. If you have any concerns about the ethical conduct of the research you may contact the Committee through the Human Ethics Committee Administrator (ph 03 479 8256). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.

Appendix 6: Personal information sheet

Personal information sheet

1. Name: ______________________

2. Gender: Please circle Male. Female

3. Age: _____________

4. Ethnicity: Please circle 1. NZ European 2. NZ Maori 3. Pacific Island 4. Asian 5. African 6. Other

5. Education levels: Please circle 1. High school 2. College or University

6. Address: ______________________

7. Phone number: ______________________

8. E-mail ________________

9. What job are you currently employed in? ______________________

10. On average how many hours a week would you work? ____________

Appendix 7: Physical Activity Readiness Questionnaire (PAR-Q)

Name: **D O B:**

Address: **Postcode:**

Email: **Mobile:**

Physical Activity Readiness Questionnaire (PAR-Q)

If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you significantly change your physical activity patterns. If you are over 69 years of age and are not used to being very active, check with your doctor. Common sense is your best guide when answering these questions. Please read carefully and answer each one honestly: check YES or NO.

1. Has your doctor ever said you have a heart condition and that you should only do physical activity recommended by a doctor?	Yes ☐	No ☐
2. Do you feel pain in your chest when you do physical activity?	Yes ☐	No ☐
3. In the past month, have you had a chest pain when you were not doing physical activity?	Yes ☐	No ☐
4. Do you lose you balance because of dizziness or do you ever lose conciousness?	Yes ☐	No ☐
5. Do you have a bone or joint problem (for example, back, knee, or hip) that could be made worse by a change in your physical activity?	Yes ☐	No ☐
6. Is your doctor currently prescribing medication for your blood pressure or heart condition?	Yes ☐	No ☐
7. Do you know of <u>any other reason</u> why you should not do physical activity?	Yes ☐	No ☐

If yes, please comment: ____________________

YES to one or more questions:
You should consult with your doctor to clarify that it is safe for you to become physically active at this current time and in your current state of health.

NO to all questions:
It is reasonably safe for you to participate in physical activity, gradually building up from your current ability level. A fitness appraisal can help determine your ability levels.

I have read, understood and accurately completed this questionnaire. I confirm that I am voluntarily engaging in an acceptable level of exercise, and my participation involves a risk of injury.

Signature ____________________

Print name ____________________

Date ____________________

Having answered YES to one of the above, I have sought medical advice and my GP has agreed that I may exercise.

Signature ____________________

Date ____________________

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the 7 questions.

Appendix 8: Pedometer log sheet (screening stage)

One-week physical activity assessment using a pedometer

Name:

Address:

Email address:

You have been given a pedometer to wear for a week baseline assessment.

How do I wear the pedometer? At the beginning of each day when you wake up wear the pedometer on your waist belt during all waking hours, except other than walking such as periods in the water (bathing, swimming) or during activities(playing basketball or soccer, running, etc.),or going to bed at night. You will also be given a log sheet to record your walks, the time of day, duration of the walk, and the total number of steps displayed on the pedometer at the end of each day (table 1)

At the end of day remove it in a place where you will see it in the morning (**beside your bed**) and remember to put it back on. Record on their activity log the date, the total number of steps displayed on the pedometer.

What about non-walking activity? If you participate in physical activity (non-walking) such as swimming, bicycling, or gardening, record the activity in the activity log (table 2).

At the end of the week return the pedometer and your activity log to researcher (Suliman mansi).

Activity log Table 1. Please fill out your walking activity at the end of each day. Do not change your lifestyle by increasing your physical activity this week.

Day/date		Time pedometer was put on	Time pedometer was taken off	Total of steps	Total minute of wearing pedometer (for office use)
1					
2					
3					
4					
5					
6					
7					

Table 2. Please fill out your non-walking activity at the end of each day.

Day/date		Type of non-walking activity	Time pedometer was taken off	Time pedometer was put on	Total minute of non-walking(for office use)
1					
2					
3					
4					
5					
6					
7					

Contact details
Suliman mansi 0226087643
Almsu521@student.otago.ac.nz

Appendix 9: The Health-Related Quality of life Questionnaire(SF-36v$_2$)

The SF-36v2™ Health Survey

Instructions for Completing the Questionnaire

Please answer every question. Some questions may look like others, but each one is different. Please take the time to read and answer each question carefully by filling in the bubble that best represents your response.

EXAMPLE

This is for your review. Do not answer this question. The questionnaire begins with the section ***Your Health in General*** below.

For each question you will be asked to fill in a bubble in each line:

1. **How strongly do you agree or disagree with each of the following statements?**

	Strongly agree	Agree	Uncertain	Disagree	Strongly disagree
a) I enjoy listening to music.	○	●	○	○	○
b) I enjoy reading magazines.	●	○	○	○	○

Please begin answering the questions now.

Your Health in General

1. **In general, would you say your health is:**

Excellent	Very good	Good	Fair	Poor	
○1	○2	○3	○4	○5	GH01

2. **Compared to one year ago, how would you rate your health in general now?**

Much better now than one year ago	Somewhat better now than one year ago	About the same as one year ago	Somewhat worse now than one year ago	Much worse now than one year ago	
○1	○2	○3	○4	○5	HT

Please turn the page and continue.

3. **The following questions are about activities you might do during a typical day. Does <u>your health now limit you</u> in these activities? If so, how much?**

	Yes, limited a lot	Yes, limited a little	No, not limited at all	
a) **Vigorous activities**, such as running, lifting heavy objects, participating in strenuous sports	O_1	O_2	O_3	PF01
b) **Moderate activities**, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf	O_1	O_2	O_3	PF02
c) Lifting or carrying groceries	O_1	O_2	O_3	PF03
d) Climbing **several** flights of stairs	O_1	O_2	O_3	PF04
e) Climbing **one** flight of stairs	O_1	O_2	O_3	PF05
f) Bending, kneeling, or stooping	O_1	O_2	O_3	PF06
g) Walking **more than a mile**	O_1	O_2	O_3	PF07
h) Walking **several hundred yards**	O_1	O_2	O_3	PF08
i) Walking **one hundred yards**	O_1	O_2	O_3	PF09
j) Bathing or dressing yourself	O_1	O_2	O_3	PF10

4. **During the <u>past 4 weeks</u>, how much of the time have you had any of the following problems with your work or other regular daily activities <u>as a result of your physical health</u>?**

	All of the time	Most of the time	Some of the time	A little of the time	None of the time	
a) Cut down on the **amount of time** you spent on work or other activities	O_1	O_2	O_3	O_4	O_5	RP01
b) **Accomplished less** than you would like	O_1	O_2	O_3	O_4	O_5	RP02
c) Were limited in the **kind** of work or other activities	O_1	O_2	O_3	O_4	O_5	RP03
d) Had **difficulty** performing the work or other activities (for example, it took extra effort)	O_1	O_2	O_3	O_4	O_5	RP04

5. **During the past 4 weeks, how much of the time have you had any of the following problems with your work or other regular daily activities as a result of any emotional problems (such as feeling depressed or anxious)?**

	All of the time	Most of the time	Some of the time	A little of the time	None of the time	
a) Cut down on the **amount of time** you spent on work or other activities	O1	O2	O3	O4	O5	RE01
b) **Accomplished less** than you would like	O1	O2	O3	O4	O5	RE02
c) Did work or other activities **less carefully than usual**	O1	O2	O3	O4	O5	RE03

6. **During the past 4 weeks, to what extent has your physical health or emotional problems interfered with your normal social activities with family, friends, neighbors, or groups?**

Not at all	Slightly	Moderately	Quite a bit	Extremely	
O1	O2	O3	O4	O5	SF01

7. **How much bodily pain have you had during the past 4 weeks?**

None	Very mild	Mild	Moderate	Severe	Very severe	
O1	O2	O3	O4	O5	O6	BP01

8. **During the past 4 weeks, how much did pain interfere with your normal work (including both work outside the home and housework)?**

Not at all	A little bit	Moderately	Quite a bit	Extremely	
O1	O2	O3	O4	O5	BP02

9. **These questions are about how you feel and how things have been with you during the past 4 weeks. For each question, please give the one answer that comes closest to the way you have been feeling. How much of the time during the past 4 weeks...**

	All of the time	Most of the time	Some of the time	A little of the time	None of the time	
a) did you feel full of life?	O1	O2	O3	O4	O5	VT01
b) have you been very nervous?	O1	O2	O3	O4	O5	MH01
c) have you felt so down in the dumps that nothing could cheer you up?	O1	O2	O3	O4	O5	MH02
d) have you felt calm and peaceful?	O1	O2	O3	O4	O5	MH03
e) did you have a lot of energy?	O1	O2	O3	O4	O5	VT02
f) have you felt downhearted and depressed?	O1	O2	O3	O4	O5	MH04
g) did you feel worn out?	O1	O2	O3	O4	O5	VT03
h) have you been happy?	O1	O2	O3	O4	O5	MH05
i) did you feel tired?	O1	O2	O3	O4	O5	VT04

10. **During the <u>past 4 weeks</u>, how much of the time has your <u>physical health or emotional problems</u> interfered with your social activities (like visiting friends, relatives, etc.)?**

All of the time	Most of the time	Some of the time	A little of the time	None of the time	
O1	O2	O3	O4	O5	SF02

11. **How TRUE or FALSE is <u>each</u> of the following statements for you?**

	Definitely true	Mostly true	Don't know	Mostly false	Definitely false	
a) I seem to get sick a little easier than other people	O1	O2	O3	O4	O5	GH02
b) I am as healthy as anybody I know	O1	O2	O3	O4	O5	GH03
c) I expect my health to get worse	O1	O2	O3	O4	O5	GH04
d) My health is excellent	O1	O2	O3	O4	O5	GH05

Appendix 10: International Physical Activity Quesionnarrire (IPAQ-sf)

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.
Think about all the **vigorous** activities that you did in the **last 7 days**. **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think *only* about those physical activities that you did for at least 10 minutes at a time.

1. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, aerobics, or fast bicycling?

   _____ **days per week**

   ☐ No vigorous physical activities → ***Skip to question 3***

2. How much time did you usually spend doing **vigorous** physical activities on one of those days?

   _____ **hours per day**
   _____ **minutes per day**

   ☐ Don't know/Not sure

Think about all the **moderate** activities that you did in the **last 7 days**. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

3. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

   _____ **days per week**

   ☐ No moderate physical activities → ***Skip to question 5***

4. How much time did you usually spend doing **moderate** physical activities on one of those days?

   _____ **hours per day**
   _____ **minutes per day**

   ☐ Don't know/Not sure

Think about the time you spent **walking** in the **last 7 days**. This includes at work and at home, walking to travel from place to place, and any other walking that you might do solely for recreation, sport, exercise, or leisure.

5. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time?

   _____ **days per week**

   ☐ No walking → ***Skip to question 7***

6. How much time did you usually spend **walking** on one of those days?

_____ **hours per day**
_____ **minutes per day**

☐ Don't know/Not sure

The last question is about the time you spent **sitting** on weekdays during the **last 7 days**. Include time spent at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television.

7. During the **last 7 days**, how much time did you spend **sitting** on a **week day**?

_____ **hours per day**
_____ **minutes per day**

☐ Don't know/Not sure

This is the end of the questionnaire, thank you for participating.

Appendix 11: Physical Activity Self-Efficacy Scale

Physical activity self- efficacy scale

Name: **Date:**

Please put a check (✓) in one of the boxes to the right item that best matches how you feel. **How confident you are that you could exercise in each of the following situations…**	**(1)** **Not at all confident**	**(2)** **Slightly confident**	**(3)** **Moderately confident**	**(4)** **Very confident**	**(5)** **Extremely confident**
1. When I am tired.					
2. When I am in a bad mood.					
3. When I feel I do not have time.					
4. When I am on vacation.					
5. When it is raining or snowing.					

Appendix 12: Intervention group: Log book

Weekly activity log

ID: Your goal setting is: Date:

How do I wear the pedometer? At the beginning of each day when you wake up wear the pedometer on your waist belt during all waking hours, except other than walking such as periods in the water (bathing, swimming) or during activities(playing basketball or soccer, running, etc.),or going to bed at night.
At the end of day remove it in a place where you will see it in the morning (**beside your bed**) and remember to put it back on. Record on your activity log the total number of steps displayed on the pedometer, and reset a pedometer to zero at the beginning of each day.

What about non-walking activity? If you participate in physical activity (non-walking) such as swimming, bicycling, running or gardening, record the activity in the activity log (table 2).

At the end of the week return your activity log to researcher (Suliman mansi).

Activity log Table 1. Please fill out your steps at the end of each day.

Date	Time pedometer was put on	Time pedometer was taken off	Total of steps	Total hours of wearing pedometer (for office use)
Wednesday 27/3/2013				
Thursday 28/3/2013				
Friday 29/3/2013				
Saturday 30/3/2013				
Sunday 31/3/2013				
Monday 1/4/2013				
Tuesday 2/4/2013				
Average				

Table 2. Please fill out your non-walking activity at the end of each day.

Date	Type of non-walking activity	Time pedometer was taken off	Time pedometer was put on	Total minute of non-walking(for office use)
27/3/2013				
28/3/2013				
29/3/2013				
30/3/2013				
31/3/2013				
1/4/2013				
2/4/2013				

Contact details

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Appendix 13: Pedometer Feasibility Questionnaire

Please read the following questions and circle the number that best reflects your response.
Name…………………………… Date:…………………………..

1. How difficult was it to use the pedometer?

1	2	3	4	5
Very difficult	Slightly difficult	Moderately easy	Very easy	Extremely easy

2. How useful were the supporting materials (e.g. step-count record card, information on walking, pedometer instruction)?

1	2	3	4	5
Not at all useful	Slightly useful	Moderately useful	Very useful	Extremely useful

3. How effective was the pedometer in motivating you to become more active?

1	2	3	4	5
Not at all effective	Slightly effective	Moderately effective	Very effective	Extremely effective

4. How easy was it to achieve the recommended targets?

1	2	3	4	5
Not at all easy	Slightly easy	Moderately easy	Very easy	Extremely easy

5. For how many weeks did you use the pedometer?

1	2	3	4	5
1-2 weeks	2-4 weeks	4-7 weeks	7-10 weeks	10-12 weeks

6. How committed are you to maintaining a physically active lifestyle?

1	2	3	4	5
Not at all committed	Slightly committed	Moderately committed	Very much committed	Extremely committed

7. Will you continue to use the pedometer to monitor your step-counts?

1	2	3	4	5
No	Probably not	Maybe	Probably	Yes

8. Please provide any adverse events you have about wearing the pedometer that you think we, as the researcher's, ought to know.
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

9. Please provide any comments you have about the intervention components that you think we, as the researcher's, ought to know.
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

Thank you for your time