The metabolic effects of limb loaded wearable resistance at varying loads and placements while walking at a moderate intensity.

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Table of Contents

LIST OF FIGURES

LIST OF TABLES

CANDIDATE CONTRIBUTIONS TO CO-AUTHORED PAPERS

Chapter 3: The metabolic effects of limb loaded WR at various loads and placements while walking at a moderate intensity	Robert 80%, John 10%, Carl 10%

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ATTESTATION OF AUTHORSHIP

I hereby declare that this submission is my own work and that to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the qualification of any degree or diploma of a university or other institution of higher learning, except where due acknowledgement is made.

Robert Grant

Date 25/11/2020

Signatures

John Cronin

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ABBREVIATIONS

NCD	Non communicable disease
WR	Wearable resistance
$\dot{V}O_2$	Volume of oxygen
$\dot{V}O_{2max}$	Maximal oxygen consumption
HR	Heart rate
EE	Energy expenditure
BM	Body mass

UNITS OF MEASUREMENT

Litres per minute	($L.min^{-1}$)
Beats per minute	(bpm)
Kilocalorie per hour	(Kcal/hr)
Effect size	(ES)
Years	(yr)
Centimetre	(cm)
Kilogram	(kg)
Kilogram square meter	($kg.m^{-2}$)
Millilitres per kg, per minute	($ml.kg^{-1}.min^{-1}$)
Percent	(%)

ETHICAL APPROVAL

Ethical approval for this research was obtained from the Eastern Institute of Technology committee (reference 19/16) on the 20th of May 2019 (see Appendix 1).

ABSTRACT

Obesity and cardio metabolic disease have become prevalent in New Zealand. It is clear that New Zealand is now dealing with a public health crisis that has never before been experienced. Diet and exercise habits are key factors that can influence the likelihood of obesity and cardio metabolic disease. Exercise in particular is now more important than ever considering the sedentary nature of the modern way of living. Technology, office work, transportation methods, etc., mean people spend long hours sitting. Researchers have suggested interspersing long periods of sitting with intermittent bouts of physical activity is key. Furthermore, people have a perception that there is a lack of time to set aside for exercise citing many differing life commitments as getting in the way. Thus people who are short on time and often spend long periods each day being sedentary require a novel and effective method of exercising that is easily accessible and able to minimise time cost.

Walking is the most common form of exercise in the world and in New Zealand. The 10,000 step rule has been used as a gold standard guideline for daily walking for many years. However, researchers are beginning to show that 10,000 steps may be an unrealistic goal and a guideline that is far too generic, particularly as 10,000 steps takes a long time (~90 mins) and is therefore unappealing to those looking for time-efficient physical activity guidelines. Therefore increasing the metabolic cost of walking may solve the issues outlined above. Walking is an easily accessible form of exercise that can be intermittently dispersed throughout a person’s day and secondly increasing the metabolic cost of walking would decrease the required amount of time set aside for physical activity. Researchers have investigated a variety of ways to increase the metabolic cost of walking such as trunk loading, Nordic walking and limb loading. Trunk loading has been shown to have possible energy-saving effects at low loads and is therefore not ideal. Nordic walking requires poles and training to use the poles effectively, which could be a barrier for participants. However, limb loading has shown promise as it allows for subjects to utilise their normal walking gait while requiring little to no training or experience. Therefore the purpose of this thesis was to examine the metabolic effects of varying peripherally loaded limb conditions using wearable resistance (WR) while walking.

Thirteen volunteers from the general population walked at a moderate to vigorous intensity (between 5 km/hr and 6 km/hr) with; no load, leg loading, arm loading and combined arm/leg loading using 2% and 4% of their body mass. The main findings for the 4% loading are reported in this abstract however, significant ($p <0.05$) but smaller changes were noted for the 2% condition. The main findings were as follows; significant increases in Energy Expenditure (EE) for legs at 4% BM (% Change = 4.9%; ES = 0.22) and combined at 4% BM (% Change = 5.1%; ES 0.24). Similarly there was a significant increase in EE at 4% BM for arms (% Change = 3.1%; ES = 0.17). Position of load did not have a significant effect ($p = 0.21$) on EE, however the magnitude of loading was found to have a significant effect ($p < 0.001$) on EE. Significant increases in $\dot{V}O_2$ for legs at 4% BM (% Change = 4.6%; ES = 0.24) and combined at 4% BM (% Change = 5.2%; ES = 0.29). Similarly there was a significant increase in $\dot{V}O_2$ for arms at 4% BM (% Change = 2.9%; ES = 0.19). Position of load did not have a significant effect ($p = 0.182$) on $\dot{V}O_2$, however the magnitude of loading was found to have a significant effect ($p < 0.001$) on $\dot{V}O_2$. There were Significant increases in Heart Rate (HR) for legs at 4% BM (% Change = 7.8%%; ES = 0.56) and combined at 4% BM (% Change = 6.6%; ES 0.43). There was a significant increase in HR at 4% BM for arms (% Change = 5.4%; ES = 0.35). Position of load did not have a significant effect ($p = 0.069$) on HR, however the magnitude of loading was found to have a significant effect ($p < 0.001$) on HR.

Wearable resistance was found to affect the variables of interest; however, it is unlikely the loads and the velocity used would have major effects on the energetic cost of walking (~17 Kcal/h for leg and combined loading conditions at 4% body mass load). However, it should be considered that this additional overload if repeated on many occasions, will have a cumulative effect. Furthermore, because WR provides a mechanical stress overload, it is possible that such loading will strengthen the involved musculature over time.

CHAPTER 1: INTRODUCTION

Rationale and significance of Thesis

Deliberate physical activity plays a significant role in both the prevention of and recovery from a host of cardio-metabolic related diseases. Current international guidelines recommend that adults complete at least 150 minutes per week of moderate-intensity or 75 minutes of vigorous-intensity aerobic-based physical activity per week (Anoop Misra, 2012; Ministry of Health, 2017; Piercy et al., 2018; Tremblay et al., 2011). Additionally, there is a recommendation to include muscle-strengthening activities of moderate or greater intensity on two or more days per week. Research has indicated that the chances of a cardiovascular event are reduced by around 50 times for those individuals meeting the recommended exercise guidelines (Riebe, Ehrman, Ligouri, & Magal, 2018).

Numerous public health researchers and practitioners over the last decade have promoted walking as a suitable aerobic physical activity. Walking is the most commonly utilized method for recreation and physical activity in New Zealand with two out of three adults participating regularly (Ministry of Health, 2020). In fact, researchers have found that walking is the predominant form of physical activity undertaken in any society throughout the world (Tudor-Locke, Hatano, Pangrazi, & Kang, 2008). The New Zealand Ministry of Health (2020) reported that walking is a low-risk mode of exercise that can be performed at any age and fitness level and provides numerous health benefits.

The most frequently utilised guideline for daily walking duration is the 10,000 step rule developed in Japan (Choi, Pak, Choi, & Choi, 2007). The accumulation of 10,000 steps per day is suggested to provide an appropriate metabolic load to promote gains in physical fitness and associated health benefits (Kang, Marshall, Barreira, & Lee, 2009). The 10,000 steps per day is equivalent to ~1 hour of moderate-intensity walking or ~300-400 kcal/day energy expenditure depending on age and size of the individual (Tudor-Locke & Bassett, 2004; Tudor-Locke et al., 2008). The 10,000 steps goal is achievable for many, however, there remains a large group of low-activity individuals who fail to reach this target. Even studies on healthy young adult participants have consistently shown average step accumulations well-below the 10,000 steps recommendation (Tully & Cupples, 2011).

One of the reasons often cited for failing to reach the daily exercise target is lack of time (Arzu, Tuzun, & Eker, 2006; Chinn, White, Harland, Drinkwater, & Raybould, 1999). The failure of individuals to reach minimal daily activity recommendations due to time constraints directly influences health status and increases cardiovascular risk. Evidently, there is a need to develop methods to increase physical activity and daily energy expenditure without increasing the time required to achieve this goal.

One suggested way to increase exercise load (and thus energy expenditure) has been to increase the individual's carriage mass during walking; this has generally been achieved by the addition of upper body loading (via backpacks or weighted vests). However, researchers have documented energy-saving effect at low walking speeds (<3.8kmh) with the addition of trunk loading (Abe, Yanagawa, & Niihata, 2004; Bastien, Willems, Schepens, & Heglund, 2005). As such utilisation of trunk loading with the intent of increasing metabolic cost during walking may not be a credible option and a possible alternative is limb loading (arms and/or legs). Fallon (2009) investigated the effects of limb loads (arms and legs combined – each weight had a mass of ~3.4kg per limb) during walking activity. While the study did not report energy costs directly, it did find a significant increase (ES = moderate at 0.62) in oxygen consumption ($\dot{V}O_2$) which is associated with an increase in metabolic cost. Similarly, an earlier study investigating the effects of walking with additional hand, wrist or ankle weights found significantly greater $\dot{V}O_2$ and heart rate but no effect on blood pressure, with three limb loading patterns when compared to a "no additional-load" condition (Graves, Martin, Miltenberger, & Pollock, 1988). Overall, it appears that limb loading in various patterns may offer a viable means of increasing energy expenditure during walking activities. This additional loading may allow individuals who do not meet the recommended duration of physical activity requirements to enjoy the proposed health benefits via higher intensity lower volume, wearable resistance loaded activity.

Research Aims and Hypothesis

The overarching question of this thesis was, does the use of distal limb loaded WR increase the metabolic cost of walking? To answer this question, the main aim of this thesis was to:

- Determine to metabolic effects of limb loaded WR at varying loads and placements while walking at a moderate intensity.

The following hypothesis was created for the study undertaken in this thesis:

- Limb loaded WR would significantly increase the metabolic cost of walking, however the magnitude of this increase is currently unknown.
- The effectiveness of WR loading would be affected by both the position of load and the magnitude of loading.

Originality of the Thesis

The originality of the thesis is reflected in the following observations:

1) Very few studies exist examining the effects of limb loaded WR on the metabolic effects of walking.
2) There is a lack of current research into the effects of limb loaded WR on the metabolic cost of walking.
3) The use of WR is a potentially novel way of improving health outcomes by increasing the metabolic cost of exercise as well as strengthening the involved musculature.
4) In a society of people lacking time, WR could be an effective way to decrease the time cost of exercise.

Framework of the Thesis

This thesis aimed to determine the metabolic effects of differing WR limb loading and placement conditions on the metabolic cost of walking and has been organised into five chapters. Chapter one contains an introduction encompassing research aims, hypothesis, originality of thesis and framework of the thesis. Chapter two is a literature review examining health in New Zealand, physical activity guidelines, the 10,000 step rule and differing ways of increasing the metabolic cost of walking. Chapter three is a research paper with the title; the metabolic effects of limb loaded WR at varying loads and placements while walking at a moderate intensity. Chapter four summarises the main findings, makes practical applications for the use of WR and outlines further research ideas. The references are located in their entirety after chapter 4 in a comprehensive list. Any appendix referred to throughout this thesis is found after the reference section under the heading Appendices. Finally, this thesis is by publication so there will be repetition throughout the thesis.

CHAPTER TWO: LITERATURE REVIEW

Introduction

Throughout the world, obesity has tripled since 1975, and it is now commonplace for obesity to be the leading factor in death, instead of people being underweight and dying from starvation (World Health Organisation, 2020). New Zealand has one of the highest obesity rates with 1 in 3 adults being classified as obese (Ministry of Health, 2019). The New Zealand Ministry of Health (2019) epidemiologists stated that obesity is an important and modifiable risk factor associated with many cardio-metabolic diseases. The World Health Organisation (2018) attributes 71% of deaths globally each year to non-communicable disease (NCD). Cardiovascular disease is the number one NCD causing premature death, followed by cancer and diabetes. Physical inactivity is one of the key risk factors identified for decreasing the risk of becoming obese and increasing the risk of a NCD (World Health Organisation, 2018). Congruently physical inactivity and long periods sitting are strongly associated with an increase in the prevalence of cardio-metabolic disease (Engelen et al., 2017; Healy, Matthews, Dunstan, Winkler, & Owen, 2011). Therefore, physical activity must be conducted deliberately as it is vital for prevention, management and recovery from a host of cardio-metabolic related diseases (Denham, O'Brien, & Charchar, 2016; Engelen et al., 2017; Healy et al., 2011). Thus it is important to break up long periods of inactivity and to conduct regular targeted physical activity to combat the risk of obesity and cardio-metabolic disease.

Barriers to physical activity have been investigated with the most commonly referred to as a lack of time (Arzu et al., 2006; Chinn et al., 1999; Justine, Azizan, Hassan, Salleh, & Manaf, 2013). Lack of motivation was also a common theme (Ball, Crawford, & Owen, 2000; Chinn et al., 1999; Justine et al., 2013). Some suggested a lack of transportation to walking-friendly places (Chinn et al., 1999), family responsibilities (Arzu et al., 2006) and money (Chinn et al., 1999) as barriers to exercise. Obese populations were also asked what their barriers to exercise were, and many cited a lack of perceived sporting ability and embarrassment (Ball et al., 2000).

Walking could be the answer to many of the aforementioned barriers, such as a lack of transportation, money and perceived sporting ability. However, lack of motivation and particularly time which were the predominant barriers are hard to overcome. A variety of research has looked into increasing the metabolic cost of walking as a means of addressing time issues. Researchers have investigated trunk loading (Abe et al., 2004; Bastien et al., 2005; Keren, Epstein, Magazanik, & Sohar, 1981; Puthoff, Darter, Nielsen, & Yack, 2006), Nordic walking (Figard-Fabre, Fabre, Leonardi, & Schena, 2010; Morgulec-Adamowicz, Marszałek, & Jagustyn, 2011; Schiffer et al., 2006; Schiffer, Knicker, Montanarella, & Strüder, 2011) and limb loaded wearable resistance (WR) (Abe et al., 2004; Fallon, 2009; Graves et al., 1988; Macadam, Cronin, & Simperingham, 2017). These loading methods may also be a way to improve motivation for walking due to the decrease in time required to achieve greater metabolic costs and the addition of variety to walking.

As outlined above, physical activity is a vital part of combatting the prevalence of obesity and cardio-metabolic disease. Therefore, the purpose of this literature review was to examine walking as a form of physical activity and to determine methods of increasing the metabolic cost of walking. The literature review consists of two main sections. First, a physical activity section examines worldwide guidelines for physical activity, walking as a form of physical activity, the 10,000 step rule and, established walking intensities based on velocity. The second section discusses methods that increase the metabolic cost of walking; trunk loading, Nordic walking and the use of limb loaded WR. Such a treatise of literature should allow for gaps in the current understanding of walking for improving health outcomes to be identified and provide insight into the possible uses of an added load to increase the metabolic cost of walking.

Physical Activity Guidelines

A lack of physical activity in society and the potential ramifications make it important to determine what an appropriate level of physical activity actually encompasses. The American College of Sports Medicine (ACSM) guidelines have recommended that adults conduct 150 to 300 minutes of physical activity each week at a moderate intensity or 75 to 150 minutes of vigorous physical activity. The

ACSM also suggested the addition of two days of strengthening exercises each week (Piercy et al., 2018). The Canadian guidelines (Tremblay et al., 2011) similarly suggested 150 minutes a week of moderate to vigorous physical activity accumulated in at least 10-minute bouts and a further two strengthening sessions each week. Indian exercise guidelines (Anoop Misra, 2012) are similar; however, Indian guidelines also suggest at least 60 minutes a day of physical activity. This physical activity is ideally comprised of 30 minutes of aerobic activity, 15 minutes of physical labour and 15 minutes of muscle-strengthening activities (Anoop Misra, 2012). The New Zealand Ministry of Health (2017) recommends at least 150 minutes a week of moderate or 75 minutes of vigorous physical activity spread throughout the week, two days a week of muscle-strengthening activities and for extra health benefits five hours of moderate or 90 minutes vigorous physical activity each week (Ministry of Health, 2017). It would seem there is some international agreement in the weekly recommended physical activity guidelines, i.e. at least 150 minutes of moderate physical activity each week and two days of strengthening activities.

Walking has been identified as the primary source of physical activity in the world, and many guidelines have been proposed by various organizations and governing bodies. The most prevalent guideline is the 10,000 step rule which has been associated with a level of physical activity that improves health outcomes (Tudor-Locke et al., 2008; Wang, Zhang, Xu, & Jiang, 2013). The value of 10,000 steps has been touted particularly by the media and is recommended all over the world (Kang et al., 2009; Tudor-Locke & Bassett, 2004). The 10,000 step rule originated in Japan, and that is where the first-ever step counter was developed. The step counter was named ‘Manpo-Kei’ which has a literal translation of ‘10,000 steps meter’ (Kang et al., 2009; Tudor-Locke & Bassett, 2004; Tudor-Locke et al., 2008). Japanese walking clubs aim for the 10,000 step mark, making it an ingrained part of the Japanese walking culture (Tudor-Locke & Bassett, 2004). The 10,000 step guideline was said to decrease the risk of coronary heart disease and be the perfect number of steps as a physical activity guideline (Bassett, Toth, LaMunion, & Crouter, 2017). Choi et al. (2007) stated that 10,000 steps is recommended in many government booklets and throughout online sources and can be achieved through adding 30 minutes intentional walking each day on top of regular daily activity. However, more recently researchers have shown changing perspectives of the 10,000 step rule and government guidelines have changed drastically in recent years (Anoop Misra, 2012; Ministry of Health, 2017; Piercy et al., 2018; Tremblay et al., 2011). Thus while the 10,000 step guideline is popular, recent research into public health recommendations seem to be steering away from this suggestion.

Increasing step counts has shown beneficial effects on markers of health when utilised by groups with hypertension and diabetes (Tudor-Locke & Bassett, 2004). Furthermore, increases in step rate have been associated with lower mortality rates in older women (Abbasi, 2019). Researchers have even suggested 5000 steps per day to be a point at which a drop in the risk of metabolic syndrome is experienced (Bassett et al., 2017). However, 5000 steps is half the commonly touted guideline of 10,000 steps. Thus while the notion that increasing step counts leads to better health outcomes is logical, there is discussion surrounding the number of steps required to do so effectively.

New Zealand public health physical activity recommendations suggest an equivalent of 21 – 22 minutes of moderate physical activity each day (Ministry of Health, 2017). Tudor-Locke and Bassett (2004) noted that 10,000 steps utilised the equivalent of between 300 kilocalories (kcal) and 400 kcal a day in energy. Alternatively, 30 minutes of walking equates to between 3000 – 4000 steps and has been shown to invoke a 150 kcal energy cost (Tudor-Locke & Bassett, 2004). Thus New Zealand public health guidelines fall short of the 10,000 step recommendation. However, public health physical activity recommendations are meant to be performed over and above normal active lifestyles (Tudor-Locke & Bassett, 2004; Tudor-Locke et al., 2008). Thus for people to accumulate 10,000 steps each day following public health guidelines (of 30 minutes moderate physical activity each day) they must be undertaking between 6000 – 7000 steps each day without any predetermined extra physical activity. Also, research has shown that healthy populations do tend to take between 6000 and 7000 steps each day (Tudor-Locke & Bassett, 2004). This, in turn, could provide evidence for the 10,000 steps a day being an unrealistic guideline assuming public health recommendations suggesting 30 minutes of moderate-intensity physical activity each day.

Activity levels recommended by many national organisations are lower than the 10,000 step rule and there is a need for further investigation. The average step count taken each day worldwide is 4961 steps (Althoff et al., 2017), young and active adults average 6000 steps each day and older adults average 4500 steps each day (Tudor-Locke & Bassett, 2004). As stated previously, the New Zealand Ministry of Health physical activity guidelines for adults increases step counts between 2413 and 2857 steps each day. Also, older adults often do not meet 10,000 steps when following the guidelines and even the best-case scenario young and active; healthy adults do not meet the 10,000 step requirement whilst following physical activity guidelines. Congruently Choi et al. (2007) revealed that for many, the daily deficit is between 3000 and 6000 steps. Thus public health guidelines do not reflect the popular 10,000 step rule and the common prescription of the 10,000 step guideline is now questionable.

As mentioned previously, increasing step count has been shown to decrease risk factors associated with metabolic disease (Kang et al., 2009; Tudor-Locke & Bassett, 2004; Tudor-Locke et al., 2008). Abbasi (2019) found that increasing step count had a direct effect decreasing the likelihood of mortality in older adult women. Furthermore, they found that the largest decrease in mortality was experienced between those that performed 2718 steps a day (275 deaths over 4.3 years) and those that did 4363 steps a day (103 deaths over 4.3 years). A 38% drop in mortality was experienced in the second group even though they only completed 1645 steps more a day (Abbasi, 2019). Considering both groups had step counts that are classified as a sedentary (lower than 5000 steps per day) (Tudor-Locke & Bassett, 2004; Tudor-Locke et al., 2008) and only a small increase in steps occurred between groups (1645 steps a day), there was a remarkable decrease in mortality.

Abbasi (2019) also investigated two more step groups 5905 vs 8442 steps each day with mortality rates of 77 and 49 individuals, respectively. It seems that there is a relationship between increasing step count and a drop in mortality. However, the decline in cases of mortality becomes smaller after the initial group revealing diminishing returns for higher step counts. It would seem that the most extensive changes in mortality are found within a population when increasing step counts for the most sedentary people. Given this information, it would be prudent to suggest that the current Ministry of

Health guidelines on physical activity are adequate and 10,000 steps is an excessive amount of steps to be promoting as a gold standard. However, further research is needed as the current literature has only investigated an older female population and may not reflect all ages and genders.

Walking and Walking Intensity

Numerous public health initiatives from recent years have promoted walking as beneficial for health and as an effective form of aerobic exercise. Two-thirds of adults in New Zealand have reported walking as a source of recreation and sport, making walking the most utilised form of physical activity (Ministry of Health, 2020). Walking is not just used as a form of recreation but also a form of transport (Kruger, Ham, Berrigan, & Ballard-Barbash, 2008). Additionally, Bauman et al. (2009) investigated the prevalence of walking in 20 countries and found contributions of between 20% and 60% to daily metabolic activity. Walking is the predominant form of exercise undertaken throughout the world regardless of gender (Dannenberg, Keller, Wilson, & Castelli, 1989; Tudor-Locke et al., 2008).

Step counting has traditionally been used to track distance and brought about the implementation of pedometers the first of which were made in Japan named Manpo Kei (Bassett et al., 2017; Kang et al., 2009; Tudor-Locke & Bassett, 2004; Tudor-Locke et al., 2008). Step counting has roots back in the history of measurement; for example, the traditional mile is supposed to be 1000 steps (Bassett et al., 2017). Tudor-Locke et al. (2008) noted that some pedometers (found in Japan) do not track steps at velocities below 3.24 km/h, which is done with the intent to place emphasis on the concept of ‘healthy steps’ which cannot be achieved at such low velocities (Tudor-Locke et al., 2008). Researchers have investigated the intensity of walking and its effect on metabolic cost (Macpherson, Purcell, & Bulley, 2009; Wang et al., 2013). Initially, pedometers were scrutinized for their inability to provide a metric for intensity (Tudor-Locke, Sisson, Collova, Lee, & Swan, 2005). However, Scruggs et al. (2003) introduced the concept of steps per minute as a guide to walking intensity which allowed pedometer users to track intensity. Furthermore, researchers have investigated step rates with the intent of classifying a given step rate and intensity value (Marshall et al., 2009; Tudor-Locke et al., 2005;

Wang et al., 2013). Researchers have shown that when walking at 3 km/h versus 6 km/h over 10,000 steps, a significant increase in energy cost occurs of 235 kcals to 388 kcals respectively (Macpherson et al., 2009). Thus the intensity of walking is a crucial concept when prescribing and undergoing physical activity.

The Ministry of Health (2017) utilised the terms ‘moderate’ and ‘vigorous’ when prescribing physical activity. Additionally, many other countries and sources also use these terms when prescribing physical activity (Anoop Misra, 2012; Ministry of Health, 2017, 2020; Piercy et al., 2018; Tremblay et al., 2011). When the terms moderate and vigorous are given alone, they are purely subjective in nature. However, the term moderate or vigorous can mean one thing to one person and something different to another. Given that walking is fundamental to human movement (Bassett et al., 2017) and the most participated form of recreational physical activity in New Zealand (Ministry of Health, 2020), future guidelines may benefit from equally succinct but slightly more practical intensity guidelines for walking.

Wang et al. (2013) found that an average of 105 steps per minute was equivalent to 3 metabolic equivalents (MET’s) a minute and related this to the desired step rate for moderate-intensity physical activity. These findings are similar with other researchers that have determined 100 steps per minute to be the optimal lower end step count per minute to be classified as a moderate intensity (Marshall et al., 2009; Tudor-Locke et al., 2005). Additionally, Wang et al. (2013) reported that 130 steps a minute is the equivalent of 6 METs per minute and likely a good goal for vigorous-intensity walking. Some gender differences were found in these studies. Males tended to reach higher metabolic costs with fewer steps (Marshall et al., 2009; Tudor-Locke et al., 2005; Wang et al., 2013). However, gender differences were not found to be significantly different, and guidelines offered were rounded to the nearest tidy step count per minute (Wang et al., 2013). Therefore the intensity of steps taken has a direct impact on the metabolic cost of the bout of exercise.

Additionally for moderate-intensity walking people should aim to reach at least 100 steps each minute. For vigorous-intensity walking people should aim for at least 130 steps each minute. These findings coupled with New Zealand physical activity guidelines give a clear and achievable metric for physical activity. Particularly as they allow the use of the readily available and inexpensive pedometer as a tool to track steps per minute.

Increasing the Metabolic cost of Walking

Humankind is remarkably adaptable opting to move in a fashion that allows for minimised energy cost (Maxwell Donelan, Kram, & Arthur, 2001; Srinivasan & Ruina, 2006; Zarrugh, Todd, & Ralston, 1974). Furthermore, during walking, people select step rates that make the task more energy efficient (Bertram & Ruina, 2001; Zarrugh et al., 1974). However, given that researchers have shown a substantial increase in obesity and metabolic disease in New Zealand and throughout the world (Engelen et al., 2017; Healy et al., 2011; Ministry of Health, 2019; World Health Organisation, 2018, 2020), perhaps it is prudent to look further into increasing energy cost of walking. Particularly when it is well documented that people lack time for exercise (Arzu et al., 2006; Chinn et al., 1999; Justine et al., 2013) and that people often lack the motivation to exercise (Ball et al., 2000; Chinn et al., 1999; Justine et al., 2013). Therefore it would be useful to increase the metabolic cost of walking to reduce the time cost of walking for exercise and therefore motivate those that otherwise may place it in the too hard basket. Increasing the energy cost of walking has been investigated using multiple techniques; trunk loading (Abe et al., 2004; Bastien et al., 2005; Puthoff et al., 2006), Nordic walking (Figard-Fabre et al., 2010; Morgulec-Adamowicz et al., 2011; Schiffer et al., 2006) and limb loading (Abe et al., 2004; Fallon, 2009; Graves et al., 1988; Macadam et al., 2017).

Trunk Loading

School children, travellers and hikers around the world wear backpacks, and this may be the most common method for humans to carry loads they would otherwise have to carry by hand long distances. Thus when looking to increase the metabolic cost of exercise trunk loading has been investigated as it is an easy and effective way of increasing load while walking (Abe et al., 2004; Bastien et al., 2005; Golriz & Walker, 2011; Keren et al., 1981; Puthoff et al., 2006). Research on the metabolic effects of trunk loading is sparse and in some cases conflicting. Puthoff et al. (2006)

investigated the impact of trunk loading at multiple walking speeds between 3 km/h – 6 km/h and various loads of 10%, 15% and 20% of body mass. They found a linear increase in oxygen consumption for all speeds and loads. As the load increased at each speed $\dot{V}O_2$ increased (Puthoff et al., 2006). These findings are congruent with Keren et al. (1981) that found higher $\dot{V}O_2$ costs for trunk loading at 20 kg over speeds ranging from 6.2 km/h to 11.2 km/h when compared to unloaded walking. Conversely, Abe et al. (2004) reported an energy-saving effect for utilising trunk loading at weights of 6 kg, 9 kg and 12 kg at a variety of speeds between 2.4 km/h to 7.2km/h. Energy cost was actually lower for trunk loaded conditions versus unloaded conditions when at low and mid-range walking speeds. Energy cost then began to even out as walking speeds reached 6.6 km/h and higher (up to the top speed utilised in the study of 7.2 km/h). However, other research by Bastien et al. (2005) found no difference in energy cost between any trunk loading conditions and the unloaded condition at any speed. This was using loads of 0 – 75% of their body mass between speeds of 1.8 km/h and 6.12 km/h.

It appears there is inconsistency within the literature surrounding the effects of trunk loading on energy cost. One confounding issue to inconsistent findings is the significant differences in methodological approaches found within trunk loading research. The loads, speeds, gradients and methods of adding load all differed, which could account for all of the differing findings. Puthoff et al. (2006) and Keren et al. (1981) suggested a linear effect on metabolic cost, Abe et al. (2004) suggested an energy-saving effect and others reported no effect (Bastien et al., 2005). Therefore further research is required to determine the real impact of trunk loading on energy cost while walking.

It needs to be noted that researchers have found a strong link between the magnitude of trunk loading and pain, discomfort and exertion (Golriz & Walker, 2011). Due to the heterogeneity of findings surrounding trunk loading and the possible negative ramifications of employing such a strategy, some caution should be exercised before using such loading.

Nordic Walking

The birthplace of Nordic walking was Scandinavia around a quarter of a century ago. It was described as a simple, easy and effective way to enhance walking and can be done by almost anyone. Nordic walking involves the use of specially designed poles that the user holds, which assist with walking allowing for heightened engagement of the upper body (Figard-Fabre et al., 2010; Tschentscher, Niederseer, & Niebauer, 2013). Nordic walking poles are designed to be similar to the poles utilised by cross-country skiers (Morgulec-Adamowicz et al., 2011). The first population known to practice Nordic walking was cross-country skiers during their summer off-season (Figard-Fabre et al., 2010). Figard-Fabre et al. (2010) investigated the metabolic cost of incline, level and decline Nordic walking versus normal walking. $\dot{V}O_2$ increased at 8%, 16% and 34% for incline, level and decline conditions respectively (Figard-Fabre et al., 2010). These findings indicate a need for consideration of gradient when performing studies and creating guidelines. Other researchers investigated adding weight to the poles used in Nordic walking. However, they found no significant increases in $\dot{V}O_2$ despite increasing pole weight up to 1.5kgs (Schiffer et al., 2011). Furthermore, research has shown that Nordic walking is superior for aerobic adaptations when compared to regular walking at the same speed. Subjects have shown significant improvement in their peak $\dot{V}O_2$ after 12 weeks of training (Figard-Fabre, Fabre, Leonardi, & Schena, 2011).

Nordic walking is a popular form of aerobic activity. Furthermore, research has investigated walking gradients (Figard-Fabre et al., 2010), the weight of poles (Schiffer et al., 2011) and also found superior benefits to aerobic fitness (Figard-Fabre et al., 2011). Tschentscher et al. (2013) concluded in a systematic review of literature that increases in $\dot{V}O_2$ (11-23%) have been found when utilising Nordic walking as compared to normal walking. It was suggested that this range might be attributed to treadmill testing versus field testing, where treadmills seem to provide much higher increases in $\dot{V}O_2$ when compared with regular field testing (Schiffer et al., 2006). Congruently Figard-Fabre et al. (2010) found an increase in $\dot{V}O_2$ of 21% while treadmill walking; meanwhile, Schiffer et al. (2006) found improvements of only 7% - 8% during field testing.

It has been concluded that $\dot{V}O_2$ is significantly increased during Nordic walking despite the fact there is heterogeneity surrounding the magnitude of $\dot{V}O_2$ increase (Morgulec-Adamowicz et al., 2011).

However, it would seem further research is required to truly determine the difference between treadmill and field testing on $\dot{V}O_2$. Furthermore, future research could look into calculating the energy cost (kcal) of exercise bouts, as all Nordic walking studies have used $\dot{V}O_2$ as an indication of energy cost and not directly calculated or measured energy cost.

Limb Loading

A lack of research exists examining the metabolic effects of limb loading while walking (Abe et al., 2004; Fallon, 2009; Graves et al., 1988). However, some research has also looked into the effect of limb loading during running (Claremont & Hall, 1988; Martin, 1985). Limb loading occurs when a subject holds weights or has weights applied to themselves in some manner. Macadam et al. (2017) suggested that increases in metabolic cost from limb loading are primarily due to an increased moment of inertia (moment of inertia = perpendicular distance of the load from the axis of rotation X mass). That is the more distal the load is placed on the limb, the greater the metabolic increase of activity (Macadam et al., 2017). Indeed $\dot{V}O_2$ and heart rate have been shown to increase when moving the same load from the thighs to the feet (Martin, 1985). However, little evidence can be found to support such a claim. Graves et al. (1988) found significantly higher $\dot{V}O_2$ cost when comparing wrist and hand loading with ankle loading. Conversely, Soule and Goldman (1969) reported that energy cost of ankle loading significantly outperformed hand loading, a finding similar to other researchers comparing 6 kg of hand loading and leg loading (Abe et al., 2004). Furthermore, some researchers have also investigated the effects of combining hand and ankle loading in one bout of exercise (Claremont & Hall, 1988; Fallon, 2009). In one study combined hand and ankle loading (2.64 L/min) induced greater $\dot{V}O_2$ costs while running than both hand (2.59 L/min) and ankle (2.58 L/min) loading alone, however, these findings were not statistically significant (Claremont & Hall, 1988). Similarly Fallon (2009) found greater $\dot{V}O_2$ costs walking at a brisk pace when combining conditions (4.23 L/min) versus leg loading (4.13 L/min) or arm loading (3.92 L/min) alone. Increases in $\dot{V}O_2$ between the combined and leg loading condition were not significant; however, the increase from the arm loading to the combined condition was significant (Fallon, 2009). Thus findings supporting a combined condition are mostly non-significant ($p = > 0.05$) and further research is needed to understand the effect of the metabolic cost of walking.

Conclusion

There is a clear need for the design of appropriate physical activity interventions to combat the rise of obesity and cardio-metabolic disease. Particularly exercise that can reduce the time constraints commonly faced today by many people living a fast-paced lifestyle. Walking is the most utilised and easily accessible form of exercise in the world, making it an ideal type of physical activity to incorporate into day to day life. Traditional walking guidelines suggest 10,000 steps a day, a guideline which has now been shown to be excessive for adults, lacking for children and severely excessive for older adults. Public health guidelines have changed for the better, prescribing more realistic and achievable bouts of physical activity. Furthermore, research has shown that the least physically active get the most significant drops in mortality from only small increases in walking.

Current physical activity guidelines are less arduous than the traditional 10,000 step rule. However, guidelines do state that walking intensity must be moderate. Moderate intensity walking pace occurs at ~100 steps or more per minute. Increasing the intensity of walking through an increased step rate is a good idea because of the higher metabolic demand. However, some research has investigated the use of additional load as one way to increase the metabolic cost of walking. Increasing the load of walking may provide an additional resistance training stimulus that increasing the velocity (step rate) of walking alone does not.

Traditionally trunk loading has been one form of increasing walking intensity. However, trunk loading has been found to have possible limiting effects on metabolic cost due to an energy-saving effect. Nordic walking has also been extensively looked at but requires equipment and training, which may be a barrier for many. Limb loaded WR has been researched primarily in jogging, running and sprinting. There is significant variation in loading, application, and methodological approach throughout studies and no conclusive findings can be drawn as to its effectiveness. However, limb loaded WR does supply a user-friendly way of increasing the intensity of walking, that warrants further investigation.

It may be that utilising a moderate walking intensity (~100 steps per minute) and then increasing intensity via limb loaded WR may induce even greater metabolic costs. Furthermore, WR may provide the addition of strength adaptations to a traditionally aerobic form of exercise. The addition of strength adaptations through WR may further assist with people’s ability to meet public health recommendations; especially now recommendations incorporate both aerobic activity and strength-based activity each week. Furthermore, the use of limb loaded WR provides more options to optimising strength adaptations compared to Nordic walking by allowing for upper and lower body targeted mechanical loading rather than just upper body loading alone. Additionally, if the energy cost of walking increases enough, then the time cost of exercise could drop even further, a desirable outcome for anyone with time constraints. Therefore limb loaded WR requires further investigation to determine its effectiveness at increasing the metabolic cost of walking at a moderate intensity.

CHAPTER THREE: The metabolic effects of limb loaded WR at varying loads and placements while walking at a moderate intensity

Abstract

Walking is one of the most common forms of physical activity prescribed to combat obesity and cardio-metabolic disease. Understanding how to increase the mechanical and metabolic benefits of this type of exercise could have health benefits to at risk populations. The purpose of this study was to examine the energy expenditure of limb loaded wearable resistance (WR) at varying loads and placements while walking. Thirteen people volunteered from the general population to participate in this study. Participants walked at a moderate to vigorous intensity with; no load, leg loading, arm loading and combined arm/leg loading using 2% and 4% of their body mass (BM). The main findings were that WR significantly ($p< 0.05$) increased Energy Expenditure (EE) (%Change = 1 to 5.1%; ES = 0.06 to 0.24) , $\dot{V}O_2$ (%Change = 0.9 to 5.2%; ES = 0.06 to 0.29) and Heart Rate (%Change = 3.0 to 7.8%; ES = 0.19 to 0.56) as compared to the unloaded condition. No significant effects were observed between body parts (arms, legs and combined); however, the 4% BM loading was found to significantly increase EE, $\dot{V}O_2$ and HR, compared to the 2% BM condition. Subjects reported adjusting to the load very quickly and stating the intensity of utilising WR as either non-existent to barely existent in ~36% of trials. It seems that the magnitude of loading used in this study had a small but significant effect on energy expenditure.

Introduction

Throughout the world, obesity has tripled since 1975, and it is commonplace for obesity to be the leading factor in death instead of people being underweight and dying from starvation (World Health Organisation, 2020). New Zealand has one of the highest obesity rates with 1 in 3 adults being classified as obese (Ministry of Health, 2019). New Zealand Ministry of Health (2019) epidemiologists stated that obesity was a critical and modifiable risk factor associated with many cardio-metabolic diseases. The World Health Organisation (2018) attributed 71% of deaths globally each year to non-communicable disease (NCD). Cardiovascular disease is the number one NCD causing premature death, followed by cancer and diabetes. Physical inactivity is one of the key risk factors identified for increasing the risk of becoming obese and increasing the risk of a NCD (World Health Organisation, 2018). Congruently physical inactivity and long periods of sitting are strongly associated with an increase in the prevalence of cardio-metabolic disease (Engelen et al., 2017; Healy et al., 2011). Therefore physical activity must be conducted deliberately as it is vital for prevention, management and recovery from a host of cardio-metabolic related diseases (Denham et al., 2016; Engelen et al., 2017; Healy et al., 2011). Thus it is important to break up long periods of inactivity and to conduct regular targeted physical activity to combat the risk of obesity and cardio-metabolic disease.

Barriers to physical activity have been investigated with the most commonly referred to barrier being a lack of time (Arzu et al., 2006; Chinn et al., 1999; Justine et al., 2013). Lack of motivation was also a common theme (Ball et al., 2000; Chinn et al., 1999; Justine et al., 2013). Some suggested a lack of transportation to walking-friendly places (Chinn et al., 1999), family responsibilities (Arzu et al., 2006), money (Chinn et al., 1999) and more as barriers to exercise. Obese populations were also asked what their barriers to exercise were, and many cited a lack of perceived sporting ability and embarrassment (Ball et al., 2000). Walking could be the answer to many of the aforementioned barriers to physical activity.

Numerous public health initiatives have promoted walking as beneficial for health and as an effective form of aerobic exercise. Two-thirds of adults in New Zealand have reported walking as a source of recreation and sport, making walking the most utilised form of physical activity (Ministry of Health, 2020). Walking is not just used as a form of recreation but also a form of transport (Kruger et al., 2008). Additionally, Bauman et al. (2009) investigated the prevalence of walking in 20 countries and found walking to contribute between 20% to 60% of daily metabolic activity. Walking is the predominant form of exercise undertaken throughout the world regardless of gender (Dannenberg et al., 1989; Tudor-Locke et al., 2008); therefore could be used as a primary form of exercise to address obesity and the modifiable risk factor associated with many cardio-metabolic diseases.

Given that researchers have shown a substantial increase in obesity and metabolic disease in New Zealand and throughout the world (Engelen et al., 2017; Healy et al., 2011; Ministry of Health, 2019; World Health Organisation, 2018, 2020), perhaps it is prudent to look further into increasing energy cost of walking. This would seem particularly relevant when one of the most reported barriers to physical activity is lack the time for exercise (Arzu et al., 2006; Chinn et al., 1999; Justine et al., 2013). Reducing the time cost of walking to achieve the same metabolic benefits may motivate those that otherwise consider physical activity as to much effort.

Increasing the energy cost of walking has been investigated using multiple techniques such as trunk loading (Abe et al., 2004; Bastien et al., 2005; Puthoff et al., 2006), Nordic walking (Figard-Fabre et al., 2010; Morgulec-Adamowicz et al., 2011; Schiffer et al., 2006) and limb loading (Abe et al., 2004; Fallon, 2009; Graves et al., 1988; Macadam et al., 2017). However, there is a distinct lack of research examining the metabolic effects of limb loading while walking (Abe et al., 2004; Fallon, 2009; Graves et al., 1988). Macadam et al. (2017) suggested that increases in metabolic cost from limb loading are primarily due to an increased moment of inertia (the perpendicular distance of the load from the axis of rotation X mass). That is the more distal the load is placed on the limb, the greater the metabolic increase of activity (Macadam et al., 2017). Indeed $\dot{V}O_2$ and Heart Rate have been shown to increase when moving the same load from the thighs to the feet (Martin, 1985). Research has reported inconsistent findings relating to the most effective loading method with some research indicating arm loading induces a greater energy cost then leg loading (Graves et al., 1988) and other research suggesting the opposite (Abe et al., 2004; Soule & Goldman, 1969). Furthermore, research has also investigated the use of a combined (arm and leg) loading condition and found it induces greater metabolic costs then leg and arm loading, however, these increases were mostly non-significant (Claremont & Hall, 1988; Fallon, 2009). Thus there is inconsistency within the literature regarding the best loading method, and further research is warranted to determine the most effective limb loading strategy. Additionally magnitude of loading differed significantly between studies and also requires further investigation. All other studies utilised abosolute loads (Claremont & Hall, 1988; Fallon, 2009; Graves et al., 1988; Soule & Goldman, 1969) and this study will be the first to use relative loading. Therefore the purpose of this study is to examine the metabolic effects of limb loaded WR at varying loads and placements while walking. It was hypothesised that; 1) limb loaded WR would significantly increase the metabolic cost of walking, however the magnitude of this increase is unknown; and, 2) the effectiveness of WR loading would be determined by both the position of load and the magnitude of loading.

Methods

Experimental Approach to the Problem

The study was a randomised crossover trial. Participants initially reported to the Eastern Institute of Technology sports science laboratory to; record demographic data, complete treadmill familiarisation, and determine the treadmill velocity to be utilised for them throughout the study and undergo maximal $\dot{V}O_2$ exercise testing. The experimental trials consisted of three incrementally loaded walking tests, each completed at the same speed and gradient. Loading conditions tested were an arm loading condition, a leg loading condition and a combined leg and arm loading condition. Participants were required to avoid food and caffeine for at least two hours before testing, avoid strenuous physical activity for 24 hours before testing and always to wear the same clothing (particularly footwear).

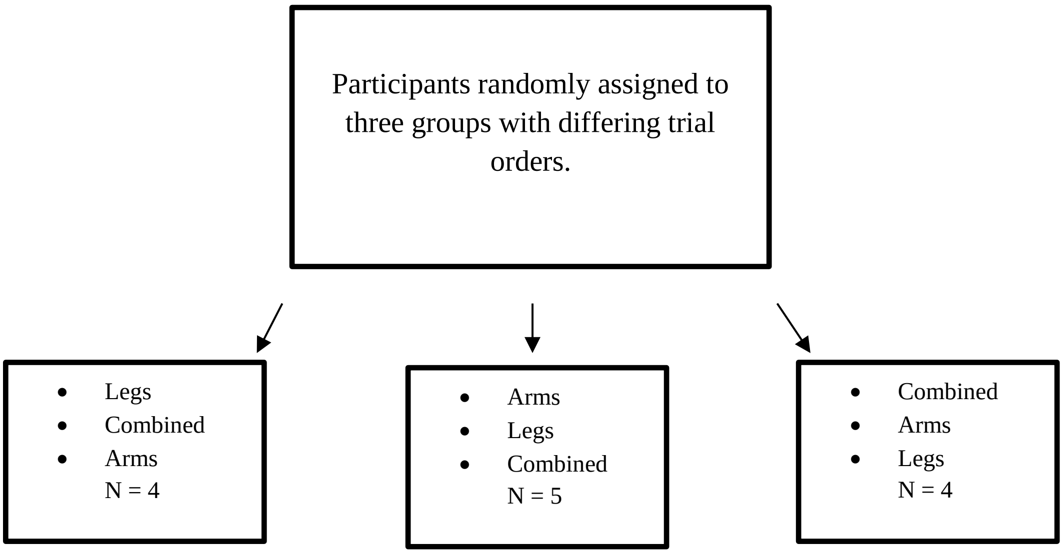
Subjects

Thirteen healthy participants (males $n = 5$ and females $n = 8$) aged 46 ± 14 years volunteered to participate in this study, the characteristics of which are shown in Table 1. All participants regularly participated in a range of recreational physical activity. Participants completed a written informed consent (see Appendix 3) and were advised of the procedures and possible risks of participating. Ethics approval was gained for this study through the Eastern Institute of Technology - reference 19/16. The information for research participants and informed consent used for this study are found in the appendix.

Table 1: Participant characteristics

All participants **(*n = 13 Male = 5 Female = 8*)**	
Age (yr)	46 ± 14
Height (cm)	173 ± 7
Weight (kg)	77.01 ± 13.98
BMI (kg.m^{-2})	25.7 ± 3.4
$\dot{V}O_{2max}$ (ml.kg^{-1}.min^{-1})	39 ± 7

Figure 1: Flow chart of experimental trial groups



$\dot{V}O_{2max}$ Protocol:

Each participant completed a standardised warm-up before the maximal test began. Participants walked on a treadmill for two minutes at a self-selected comfortable walking pace. Then they walked on a treadmill set at a 1% gradient at 5 km/hr for two minutes followed by 5.5 km/hr for two minutes and then 6 km/hr for two minutes. After the warm-up participants were asked which of the three walking speeds felt like a moderate intensity that was manageable for long periods, the load each participant chose was subsequently used for the maximal test and each experimental trial of the study. After the initial walking warm-up subjects underwent a variety of dynamic stretches (10 repetitions of each). The dynamic stretches consisted of ankle plantarflexion to dorsiflexion, leg swings (sided to side and front to back), bodyweight squats and lunges (five on each side).

A maximal test performed on a treadmill (Technogym, Italy) with a walking protocol was used (personal communication with Doctor Carl Paton). Participants were fitted with two heart rate monitors (Polar Electro Oy, Finland) and Garmin (920 XT; Garmin international, Olathe, KS), connected to a metabolic system and then placed on the treadmill. The treadmill was set to the speed chosen during the warmup outlined above and remained constant. The gradient began at 1% and was increased by 1% each minute until volitional fatigue was reached. $\dot{V}O_{2max}$ was determined as the highest 30-second oxygen uptake value recorded in the test. An hour before testing began the metabolic systems (Metalyzer 3B, Cortex Biophysik, Germany) volume, room air and Alpha gases (15% O_2 and 5% CO_2) were all calibrated according to manufacturer guidelines.

Incrementally Loaded Walking Tests:

After completion of pre-testing, particpants were randomly allocated into three separate groups. Five of them in the Leg, Arm and Combined group, Four in the Arm, Combined and Leg group and the last four in the Combined, Leg and Arms group (see Figure 1). Participants then performed three days of testing in the test order they were randomly assigned. Three different orders were used to combat the possibility of an order or fatigue effects in the study. For the leg loading condition, Exogen shin garments were placed on participants. Exogen arm garments were placed on the forearm and upper arm in the arm loading condition. For the combined condition, both the shin and arm Exogen garments were worn (see Figure 2).

Figure 2: Exogen exoskeleton compression garments with load (legs, arms and combined).

For each day of testing the appropriate Exogen, garment was worn. Two heart rate monitors were placed on subjects, one Polar and the other Garmin. The Polar heart rate monitor measured heart rate through a calibrated metabolic system (Cortex 3b Metalyzer Germany). The Garmin monitor measured step rate per minute. Participants also wore a Metalyzer mask and volume sensor with incorporated oxygen sensor. Heart rate (HR), volume of oxygen ($\dot{V}O_2$), energy expenditure (EE), step rate, and respiratory exchange ratio (RER) were all recorded throughout the testing.

Participants walked on the treadmill at a 1% gradient at the individualised speed (determined in their initial session). The participant then walked with no added load for six minutes and at six minutes, got off and sat down for four minutes. Two percent of the participants bodyweight was then applied to the appropriate Exogen garment placed as distally as possible. The participant then completed another six minutes with the 2% bodyweight load and once again got off and sat for four minutes of passive seated recovery. During the second four minutes, the load on the Exogen garments was increased to

4% of bodyweight. Particpants then completed the last six-minute walk with the 4% bodyweight. Subjects were then given a cooldown upon completion of the trial.

Statistical Analysis:

Means and standard deviations were calculated as measures of centrality and the spread of data. Normality (Shapiro-Wilk) and outlier analysis (box and whisker plots) was undertaken prior to testing for significant differences, which were determined using a two way repeated-measures analysis of variance (ANOVA). Where appropriate subsequent post-hoc analysis using the Tukey test was performed. In addition, percent change between each of the three loading types were determined, and Cohens D effect size (ES) statistics were used to assess the magnitude of change between trials. Cohens D was interpreted using the following guide (Cohen, 1977); trivial: 0-0.20; Small: 0.21-0.50; Medium: 0.51-0.80; Large: 0.81-1.20; Very large: 1.20+ Alpha for significance was set to $p < 0.05$.

Results

The mean $\dot{V}O_{2max}$ in this study was 39 ± 7 ml.kg^{-1}.min^{-1}, the $\dot{V}O_{2max}$ ranged from 21 ml.kg^{-1}.min^{-1} to 51 ml.kg^{-1}.min^{-1}. The highest percent of $\dot{V}O_{2max}$ reached during testing was 93%, and the lowest was 30%. The average percentage of $\dot{V}O_{2max}$ achieved in each trial can be observed in Table 2, subjects consistently reaching mean intensities between 52% ± 17% and 55% ± 19% of $\dot{V}O_{2max}$.

Table 2: Mean percent of $\dot{V}O_{2max}$ obtained in each trial.

Condition	**0% Legs**	**0% Arms**	**0% Comb**	**2% Legs**	**2% Arms**	**2% Comb.**	**4% Legs**	**4% Arms**	**4% Comb.**
Mean $\dot{V}O_{2max}$ (%) (ml/kg/min)	53	52	52	54	53	53	55	54	54
Standard Deviation (%) (ml/kg/min)	19	17	17	19	17	18	19	18	18

No significant differences in $\dot{V}O_2$, HR and EE were found when examining the effect of WR placement (arms, legs and combined) across loads. However magnitude of loading (0%, 2% and 4%

of body mass) was found to be statistically significant within individual WR placement types arms, legs and combined respectively. The following discussion of these results pertains to the within placement comparison.

Table 3: Arms condition mean and standard deviation. Percent change and effect sizes.

Physiological variables	**Arms 0%**	**Arms 2%**	**Arms 4%**	**0 – 2% % Change (ES)**	**0 – 4% % Change (ES)**
$\dot{V}O_2$ (L.min^{-1})	1.44 ± 0.2	1.46 ± 0.21	1.49 ± 0.21	0.9 (0.06)	2.9 (0.19)
Heart Rate (bpm)	110 ± 16	113 ± 16	116 ± 17	3.0 (0.19)	5.4 (0.35)
Energy Expenditure (Kcal/hr)	376 ± 61	381 ± 65	388 ± 63	1.1 (0.06)	3.1 (0.17)

All results statistically ($p < 0.05$) different to each other.

The effects of arm loaded WR (2% and 4% body mass) on $\dot{V}O_2$, HR and EE can be observed in Table 3. With the addition of mass increments of ~0.03 L/min, ~3 bpm and ~6 kcal/hr for $\dot{V}O_2$, HR and EE were observed respectively. Even though changes with the addition of WR were all statistically significant, the 0% to 2% BM changes for all the variables were trivial and for the 0% to 4% loading there were small changes in HR though the other two measure were trending towards a small effect size.

Table 4: Legs condition mean and standard deviation. Percent change and effect sizes.

Physiological variables	**Legs 0%**	**Legs 2%**	**Legs 4%**	**0 – 2% % Change (ES)**	**0 – 4% % Change (ES)**
$\dot{V}O_2$ (L.min^{-1})	1.46 ± 0.26	1.50 ± 0.26	1.53 ± 0.26	2.6 (0.14)	4.6 (0.24)
Heart Rate (bpm)	110 ± 14	115 ± 15	119 ± 17	4.4 (0.32)	7.8 (0.56)
Energy Expenditure (Kcal/hr)	381 ± 76	393 ± 78	399 ± 76	3.1 (0.14)	4.9 (0.22)

All results were statistically ($p < 0.05$) different to each other.

The effects of leg loaded WR (2% and 4% body mass) on $\dot{V}O_2$, HR and EE are detailed in Table 4. With the addition of mass increments of ~0.03 L/min, ~5 bpm and ~9 kcal/hr for $\dot{V}O_2$, HR and EE were observed respectively. Changes with the addition of WR were all statistically significant ranging from 2.6% to 7.8% and effect sizes ranged from trivial ($\dot{V}O_2$ and EE at 2% BM) to moderate (HR 4% BM).

Table 5: Combined condition mean and standard deviation. Percent change and effect sizes.

Physiological variables	**Comb. 0%**	**Comb. 2%**	**Comb. 4%**	**0 – 2% % Change (ES)**	**0 – 4% % Change (ES)**
$\dot{V}O_2$ ($L.min^{-1}$)	1.43 ± 0.24	1.46 ± 0.24	1.50 ± 0.22	2.0 (0.11)	5.2 (0.29)
Heart Rate (bpm)	111 ± 15	115 ± 17	119 ± 18	3.6 (0.24)	6.6 (0.43)
Energy Expenditure (Kcal/hr)	375 ± 71	383 ± 71	393 ± 65	2.1 (0.10)	5.1 (0.24)

All results were statistically ($p < 0.05$) different to each other.

The effects of combined (arm and leg) loaded WR (2% and 4% body mass) on $\dot{V}O_2$, HR and EE are described in Table 5. ~0.03 ~4 bpm ~9 Kcal/h L/min Though changes with the addition of WR were all statistically significant, only HR was found to have a small effect at 0% to 2% BM and 4% BM resulted in small changes for all other variables (5.1% - 6.6%).

Table 6: Qualitative feedback on intensity for each trial

Common Feedback (each condition)	**Number of Times**
Felt the weight but got used to it quickly	17
Barely felt or did not feel any weight	13
Felt the weight and it made it harder	6

Table 6 displays qualitative feedback on intensity given by subjects directly after every trial in the study. It appears that participants quickly acclimated to the additional loading.

Discussion

This research aimed to establish the effects of varying limb WR loads and positions on physiological measures during treadmill walking. The main findings were: 1). There were no significant differences when the same loading magnitude was used between position/placement of load (arms, legs or combined) meaning that the loads can be used interchangeably to achieve a similar physiological effect; 2). Significant within condition (position) differences were observed between 0% - 2% and 0% - 4% BM loading; 3). Regardless of the position of loading utilised $\dot{V}O_2$ increased on average by ~0.03 L/min with every 2% of extra load added. The largest effects and percentage changes were observed in the combined loading condition at 4% BM (5.2%; ES = 0.29); 4). The largest increases in HR (~5 bpm) were observed with leg loading at 4% BM (7.8%; ES = 0.56); 5). The EE increased on average by ~9 kcal for legs and combined loading across 2% BM loading increments, the percent change and effect sizes were very similar between the leg and combined loading conditions; and, 6) Subjects reported a low perceived exertion to limb loaded WR resistance.

It was hypothesised that the effectiveness of WR loading would be affected by the position of loading, however, no significant differences in $\dot{V}O_2$, HR and EE were found when examining the effect of different WR placement (arms, legs and combined) across loads. This finding is contrary to previous research in this area. Fallon (2009) reported leg loading to be significantly greater (ES = 0.33) in $\dot{V}O_2$ cost compared to hand loading and Abe et al., (2004) found significantly higher oxygen cost for leg versus arm loading during walking and running. Conversely, other researchers have reported wrist loading ($\dot{V}O_2$; 15%; ES = 2.00) to be greater ($p < 0.05$) for $\dot{V}O_2$ and HR as compared to ankle loading ($\dot{V}O_2$; 7.7%; ES = 1.14) using an absolute load of 2.72 kg (Graves et al., 1988). In the Graves et al. (1988) study, however, subjects exaggerated the arm swing during walking by swinging their hand to the height of the shoulder, while keeping the arm bent at 90°. The exaggerated arm swing is different to all other research in this area and is likely the cause of the significant increase in $\dot{V}O_2$ and HR when comparing hand, and wrist loading to ankle loading, i.e. greater arm displacement equals greater muscular work, which translates to higher metabolic cost.

While our study did not find significant changes due to changes in the position of load, arm loading was between 1.7% and 2.4% lower in all physiological measures ($\dot{V}O_2$, HR and EE) than leg loading. Nonetheless, this study is the first to report that the effectiveness of limb loaded WR is not affected by position (arm, leg or combined) when using the same relative loading, meaning that limb loaded WR can be used in a variety of positions to induce a similar metabolic effect. This interchangeability could prevent tedium/monotony when exercising and also enable the targeted strengthening of particular parts of the body through the selective use of loading position.

Fallon (2009) demonstrated no significant ($p = 0.211$) change between the leg and combined loading conditions which was similar to this study findings. However, unlike this study, they utilised double the weight for the combined condition versus the leg condition. This study was the first in the limb loaded WR research to find that the effectiveness of limb loaded WR was not determined by position (arm, leg or combined), but instead by the magnitude of loading. Furthermore, the finding that position of the load has little effect means that limb loaded WR can be used in a variety of positions with a similar outcome. However, further research is warranted to ensure the integrity of such a statement. The interchangeable use of multiple loading positions could have two applications for WR users; 1) prevention of tedium; and, 2) targeted strengthening of particular parts of the body through the selective use of loading positions.

Though the position of loading did not make a significant change to the physiological variables of interest, the magnitude of loading certainly did with statistically significant differences (0.9 to 7.8%; ES = 0.06 to 0.56) observed across all load comparisons. These findings are congruent with other research that has shown the magnitude of loading having significant effects on $\dot{V}O_2$ (Abe et al., 2004; Fallon, 2009; Graves et al., 1988). These studies all used absolute loads of 6.8 kg (arms and legs) and 13.6 kg (combined) loads (Fallon, 2009); 2 kg, 3 kg, 6 kg (legs) and 9 kg (arms) loads (Abe et al., 2004); and, 2.72 kg (hands, wrists and ankles) loads (Graves et al., 1988). Given the different ways of loading (absolute vs relative loading used in this study) and also differing magnitudes of loading, subsequent comparisons become problematic. Nonetheless, HR was shown to significantly increase (percent changes between 1.3% - 5.3%; ES between 0.47 – 1.88) in Graves et al. (1988) and Fallon (2009) (percent changes between 1% - 3.4%; ES between 0.11 – 0.31) but was not investigated in Abe et al. (2004). Also, it should be noted that no previous research investigated EE as a variable; only $\dot{V}O_2$ was considered to be an accurate representation of energy cost. The results of this study provide a more comprehensive understanding of the effects of limb loaded WR and used loading of the subjects relative to their body mass, which provides a more individualised approach.

Regardless of the position of loading utilised $\dot{V}O_2$ increased on average by ~0.03 L/min with every 2% of extra load added, the largest $\dot{V}O_2$ loading effects were observed in the combined loading condition at 4% BM (5.2%; ES = 0.29). Fallon (2009) is the only WR study that has also published percent change between loaded and control conditions, which were 1.4% (ES = 0.09), 6.8% (ES = 0.43) and 9.2% (ES = 0.62) for arms (6.8 kg) , legs (6.8 kg) and combined conditions (13.6 kg) respectively. Percent changes in the WR conditions of Fallon (2009) were 2.2% and 4.0% greater than the leg and combined condition results of this study. The larger increases in $\dot{V}O_2$ for Fallon (2009) were not surprising, considering they used a greater loading than in this study. That is, the average loading in this study relative to the body mass was 1.54 to 3.08 kg which was substantially less than the 6.8kg (arms and legs) and 13.6 kg (combined) loading of the Fallon study.

Interestingly the trends between studies were similar in terms of the combined then legs then arms having the greatest changes in $\dot{V}O_2$. The most likely reason for the combined condition experiencing the highest percent change in $\dot{V}O_2$ is that the 2% and 4% BM loading could be placed more distally, affecting the rotational inertial and therefore mechanical and metabolic work. Graves et al. (1988) did not report percent changes or effects sizes, however, extrapolating findings from their graphs it seems that higher $\dot{V}O_2$ was associated with wrist and hand (15.4%; ES = 0.2.00) loading versus ankle (7.7%; ES = 1.14) loading. However, it needs to be considered that these authors used an exaggerated arm swing during walking, which likely explains the differential findings. Interestingly our increases in $\dot{V}O_2$ compared to the Fallon (2009) study were greater even though the loading was substantially lighter, and it may be that the extra load used in the Fallon (2009) study may have caused less arm swing and therefore a reduced $\dot{V}O_2$ cost. If that was the case, then it there may be an optimal magnitude for arm loading and movement that affects $\dot{V}O_2$ cost.

The changes in HR ranged from 3.0% (ES = 0.19) – 7.8% (ES = 0.56), in the leg loading condition at 4% BM producing the largest change in HR. It seems that HR was the most affected physiological measure in the study, as indicated by the larger percent changes and higher effect sizes.. However, these findings are not uniform with greater effects noted in the $\dot{V}O_2$ as opposed to HR results for other studies (Fallon, 2009; Graves et al., 1988). Fallon (2009) reported HR increases of 1% (ES = 0.11), 2.2% (ES = 0.17) and 3.4% (0.31) in their arm, leg and combined loading protocols, which were considerably less than our findings even though their loads were much heavier. These findings are difficult to explain, especially as both cohorts exercised at approximately the same velocity, however the differences between research may be caused by methodology. Similar to their other findings, the HRs in Graves et al. (1988) were significantly greater for wrist loading (5.3%; ES = 1.88) as compared to ankle loading (1.3%; ES = 0.47), the exaggerated arm swing once more thought to explain the differences. Thus limb loaded WR is effective in increasing the HR of walking; however, more research is needed to understand this relationship.

With regards to EE, while there was no significant change shown in any loading position, it is useful to note that both leg and combined loading conditions resulted in potentially worthwhile increases in EE of ~5% (ES = ~0.23). However, the arm EE increase was trivial (ES = 0.17) in the 4% BM condition and was ~2% less than both leg and combined conditions. The limited space on the Exogen arm sleeve may be the reason arm loading did not match the combined and leg loading conditions, especially at 4% BM when approximately half the load for each subject had to be placed more proximally which may reduce the moment inertia of the loaded arm and therefore the muscular and metabolic work. No literature has investigated EE increases when walking and using limb loaded WR, all of them opting to use $\dot{V}O_2$ as a primary metabolic measure.

In terms of the qualitative comments, 17% of the time subjects reported feeling the limb loaded WR made walking meaningfully harder. The majority of subjects (~47%) reported feeling the weight initially but quickly adapting to it, and it was also noted that the WR loading was perceived as barely noticeable by ~36% of subjects. Thus ~83% of the time subjects using 2% and 4% of BM either did not feel a change in intensity or quickly adapted to the added limb load. Additionally, a few subjects stated that the load on the legs or arms felt good and may assist with arm and leg swing. Our findings imply that larger percentages of body mass could be used in future studies; it seems with minimum discomfort.

Conclusions

Obesity and cardio-metabolic disease are now more prevalent than ever before, due to modern lifestyle and time constraints getting in the way of adequate physical activity for health. One form of exercise thought ideal for combatting these issues is walking. However, motivation and adherence to this form of exercise may benefit from varied training methods that increase metabolic cost and allow for a reduction of time cost. One proposed method is the use of WR, the effects of limb loaded WR of interest in this study. It was found that loads of 2 and 4% BM produced statistically significant increases in $\dot{V}O_2$, HR and EE, the heavier loading causing greater effects. The position of loading (arms, legs or combined) did not have a significant impact on metabolic cost, and therefore, practitioners can prescribe the arm and calf sleeves interchangeably. This study is the first WR study to utilise % BM loading instead of a predetermined absolute load, which would seem a consistent way to individualise loading.

Consideration needs to be given to loading placement given that the further the load away from the axis of rotation, the greater the moment of inertia, which directly affects mechanical, muscular and metabolic load. This affected some of the results i.e. spread of load across the arms. To increase EE therefore, it is vital that loads are distributed as distally as possible, the combined condition enabling this type of loading. Furthermore, angular displacement and angular velocity associated with walking have large effects on EE as evidenced in other research findings that used an exaggerated arm swing during walking. Finally, it seems that the technologies (Exogen WR) as well as the loads used in this study were tolerated well by the users, and there is opportunity to load the body with greater percentages of BM without seriously affecting comfort and utility.

CHAPTER 4: SUMMARY, PRACTICAL APPLICATIONS AND FUTURE RESEARCH DIRECTIONS

Summary

Obesity and cardio metabolic disease are major issues in New Zealand and throughout the world. Exercise or lack of it is a crucial lifestyle factor involved in their prevalence, and physical activity should be regularly incorporated throughout the day (particularly to break up long periods of sedentary behaviour) to begin combatting these health issues. Walking is the most commonly undertaken form of exercise in New Zealand and the world and is easily accessible and available to most people. However, modern society is so busy that people are now citing a lack of time for exercise (even walking) and thus methods of loading walking have been researched to decrease the time cost of this activity. Limb loaded WR is one method that has been investigated, however as a body of knowledge is in its infancy and therefore was the main focus of this thesis.

The literature review provided the rationale for the investigation of the metabolic effects of limb loaded WR while walking. Previous research into the topic was sparse, the findings inconsistent, and because of the variety of different methodologies, comparisons and definitive conclusions problematic. Given these limitations there appeared a need to understand the effects of WR in a health context, as most of the research has been more sporting focussed using higher velocity movement patterns, e.g. jogging, running and sprinting. This thesis, therefore, aimed to determine the metabolic effects of differing WR limb loading and placement conditions on the metabolic cost of walking. Subjects were required to walk at a moderate intensity with limb loaded WR on their arms, legs and in a combined (arms and legs) condition using 2% and 4% of body mass loads. A range of metabolic variables were measured, including EE, $\dot{V}O_2$, HR and qualitative comments were recorded from participants directly after each trial. The different WR placements and loads in this thesis were used to provide insight into the efficacy of limb loaded WR for increasing the metabolic cost of walking.

Thirteen volunteers from the general population walked at a moderate to vigorous intensity with; no load, leg loading, arm loading and combined arm/leg loading using 2% and 4% of their body mass. The main findings of this thesis were; 1) There were no significant differences between position/placement of load (arms, legs or combined) meaning that the loads can be used interchangeably to achieve a similar physiological effect; 2) Significant within condition (position) differences were observed for 0% - 2% and 0% - 4% BM loading; 3) Regardless of the position of loading utilised $\dot{V}O_2$ increased on average by ~0.03 L/min with every 2% of extra load added, the largest effects and percentage changes were observed in the combined loading condition at 4% BM (5.2%; ES = 0.29); 4) The largest changes in HR (~5 bpm) were observed with leg loading at 4% BM (7.8%; ES = 0.56); 5) The EE increased on average by ~9 kcal for legs and combined loading across 2% BM loading increments, the percent change and effect sizes were very similar between the leg and combined loading conditions; and, 6) Subjects reported a low perceived exertion to limb loaded WR resistance. However, it needs to be remembered this additional overload if repeated over many occasions will have a cumulative effect e.g. If subjects walked for 60 minutes a day with 4% BM using leg or combined loading it would result in ~17 days of extra walking each year without any extra time cost. Furthermore, because WR provides a mechanical overload, it is quite likely that such loading will strengthen the involved musculature over time.

Practical Applications

Based on the findings of this study, practical applications for health practitioners, lifestyle coaches, personal trainers and individuals would be as follows:

1) Limb loaded wearable resistance can be used to increase the EE, HR and $\dot{V}O_2$ associated with walking at a moderate intensity.
2) Heavier loading (higher percentages of body mass) has greater metabolic costs.
3) Subjects reported little to no effects on perceived exertion, and therefore, it would seem that heavier loads could be prescribed for greater energy costs with little extra discomfort.

4) It may be prudent to utilise combined loading if attempting to load beyond the 4% BM used in the current study as it allows for larger % BM loading while keeping the weight as distal as possible.
5) Though not investigated WR provides a mechanical overload that offers a strength training stimulus and not just metabolic increases as part of walking.
6) The position of load (arms, legs or combined) does not have a significant effect on metabolic cost, and therefore practitioners can prescribe the arm and calf sleeves interchangeably.
7) Given the similar metabolic costs, practitioners can choose whether to overload the arms or legs to induce specific localised strength adaptation.
8) One of the barriers to physical activity is tedium and monotony (motivation), and WR may offer a means of adding variety to physical activity that may result in greater adherence.
9) Limb loaded WR offers a myriad of variations that can challenge the neuromuscular system while walking and provide movement variability. For example, upper body loading, lower body loading, single-leg loading, contralateral loading and ipsilateral loading. This could make people more injury resistant by constantly changing agonist, antagonist and synergist contribution to walking. Such an application needs further research.

Limitations

A number of limitations to this study are outlined below;

1) The primary limitation is that the Exogen WR is unable to load more than 4% of body mass due to the size of the weights and the size of the surface area they attach i.e. arm and calf sleeves. The ability to load at higher percentages of body mass would have induced larger and possibly more meaningful change.
2) A brisk walk of between 5-6 km/h was utilised in this study to achieve a moderate walking intensity. Using higher walking speeds would likely significantly increase the metabolic cost effects of the load utilised in this study. However, when reaching speeds of 8 km/h, the

subject is no longer walking and beginning to run. Thus WR may not be the appropriate tool for walking due to its nature of having a lower velocity of movement.

3) No video analysis was utilised, and therefore the kinematic effects of limb placement on walking technique are unknown.
4) Since the loads were progressively overloaded (0% BM, 2%BM and 4% BM) and not randomised it is possible that there was a fatigue or learning effect with loading.
5) Participants gave subjectvie comments on the intensity after each bout of walking, however an RPE scale inclusion would also have been a good tool for gauging intensity.
6) The fitness levels of particpants varied widely and perhaps looking at more homogeneously fit participants would create changes in metabolic findings, particularly when using unfit versus fit groups.

Future Research

This thesis has provided novel and original information in regards to the effects of limb loaded WR on the metabolic impact of walking. However several areas require further research;

1) This study utilised loads of 2% and 4% of body mass. Statistically significant changes were shown, but the magnitude of changes was mostly trivial and small. Thus researchers could look to load at higher percentages of body mass, especially considering the subjects qualitative feedback that load was either not felt or barely felt and quickly to adapted to the additional load.
2) One of the proposed benefits of WR is that it is providing mechanical overload and whether this provides strengthening of the leg and arm muscular warrants investigation.
3) It may be that because of the possible strength adaptations subjects may be able to operate at higher intensities; however, this is speculative and needs investigation.
4) Whether heavier loading affects the segmental contribution of arms, legs and combined loading to energy expenditure will also need investigation.

5) The effect of exaggerated arm motion during walking using loading similar to this study could also be of interest to determine the increase in energy expenditure.
6) Though asymmetries were not assessed during this study, WR offers a mean to address asymmetrical issues given the unilateral loading opportunities WR provides. Using WR to address issues with gait and improve the efficacy of walking, is an interesting area warranting research.
7) In terms of injury prevention and rehabilitation WR offers a myriad of loading options that could pre-condition patients before hip, knee and shoulder surgeries.Furthermore, WR could be an effective means of loading when recovering from such operations. Again the value of such a proposition needs exploring.

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Appendices:

Appendix 1: Ethics Approval

EIT
HAWKE'S BAY
EASTERN INSTITUTE OF TECHNOLOGY
TE AHO A MĀUI

Our Ref: 19/16

20 May 2019

Dear Carl,

Thank you for your application for your research project "The effects of different limb loading patterns using wearable resistance garments on cardiovascular and metabolic demands during walking exercise." – our Ref 19/16, received by the Research Ethics and Approvals Committee.

I am pleased to inform you that your research application has been approved.

As you continue with your research, please refer to the EIT Code of Research Ethics. As a reminder, if your proposal changes in any significant way, you must inform the Committee. Please quote the above reference number on all correspondence to the Committee. Please send all correspondence to REACapprovals@eit.ac.nz.

The Committee wishes you well for the project.

Yours sincerely

Catherine Hines
Secretary - Research Ethics & Approvals Committee

Appendix 2: Information for Research Participants

Information for Research Participants

Date:	

Project Title:	The effects of different limb loading patterns using wearable resistance garments on cardiovascular and metabolic demands during walking exercise

To:	Research participants

Researcher(s):	Dr Carl Paton; *Mr Robert Grant

Affiliation:	The Eastern institute of Technology and Auckland University of Technology

Description of the research:

The aim of this research is to assess the effects of adding additional bodyweight (via wearable resistance clothing to the arms and legs) on overall energy expenditure during walking exercise. It is suggested that adding this extra weight will increase energy consumption (calories burned) and may be an effective strategy to enhance weight loss without increasing exercise duration.

What will participating in the research involve?

Provide information on factors such as where the research will take place, how much time will be involved, what activity(s) will your subjects be performing, what things you intend to measure, and whether or not audio or video tape records will be made. Delete this highlighted section prior to printing.

You will be required to complete a series (4-5) of treadmill walking tests of approximately 1 hour duration over a ~1 month period. The first test consists of treadmill familiarisation session and a baseline fitness assessment (6-minute walk test and a maximal oxygen assessment ($\dot{V}O_2$Max). The remaining sessions incorporate a three stage walking assessment using a range of limb (arm and legs) loading conditions completed at a moderate intensity pace (derived from your 6 min walk test). During trials you will undergo limb loading conditions of 0% 2% and 4% of individual bodyweight for 6 minutes at each load.

Physiological measures taken during testing will include respiratory gas analysis, heart rate and step rate. Rate of perceived exertion will also be taken during each loading condition and you may be filmed to assess the effect on your walking pattern.

Testing will be performed at the EIT sport science facilities by Dr Carl Paton and Mr Robert Grant

What are the benefits and possible risks to you in participating in this research?

By participating in this research you will be able to determine if using additional weight during walking exercise will enable you to burn more energy (Calories) and potentially reduce bodyweight. A reduction in bodyweight is recognised as being positively correlated with numerous health and well-being benefits.

Healthy Participants will be at no greater risk than they would be in participating in general recreational walking activities.

Your rights:

Delete any of the statements below which do not apply to your participants. Also delete this highlighted area prior to printing.

- You do not have to participate in this research if you do not wish to.
- If you are a student at EIT and decide to take part, you can withdraw from the research at any time and this will not affect treatment or assessment in any courses at EIT.
- Once you have completed the research you have a *<<specify an appropriate length of time>>* period within which you can withdraw any information collected from you.
- You are welcome to have a support person present (this may be a member of your family/whanau or other person of your choice)
- You may request a summary of the completed research

Confidentiality:

Provide information on how you will maintain confidentiality and implement anonymity procedures. Include a statement which says "Identifiable information about you will not be made available to any other people without your written consent". Also include a statement outlining where the data will be securely stored and for how long.

Identifiable information about you will not be made available to any other people without your written consent Raw electronic data will be held only by the principle researchers in password protected files.

Hard copies of data will be stored in a locked filing cabinet accessible by the named researchers only.

Data will be kept for a minimum of 5 years where after electronic data may be destroyed using computer programs known to remove data from computer hard drives in a manner that leaves it irretrievable. Hard copies of data will be destroyed using shredding techniques before being disposed of in secure garbage receptacles.

If you wish to participate in this research, or if you wish to know more about it, please contact

Contact Person:	Dr Carl Paton		
EIT School/Section:	School of Health and Sport Science		
Work phone #	6125	Email address	cpaton@eit.ac.nz
Mobile phone #	0212943005		

Supervisor Name(s): (if applicable)			
Work phone #		Email address	

Head of School/Manager:	Kirsten Westwood		
Work phone #	06 9748000 ext 5240	Email address	kwestwood@eit.ac.nz

For any queries regarding ethical concerns, please contact: Chair, Research Approvals Committee, EIT.
Ph. 974 8000

This study has been approved by the <<ethics committee>> on <<date>>, Reference # << >>.

Appendix 3: Informed Consent

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Research Consent Form

Project Title: The effects of different limb loading patterns using wearable resistance garments on cardiovascular and metabolic demands during walking exercise.

Researcher(s): Dr Carl Paton and Mr Robert Grant

I have read and I understand the Information for Research Participants sheet dated 01/06/2019 for volunteers taking part in this study. I have had the opportunity to discuss this study and am satisfied with the answers I have been given.

I understand I am able to withdraw all of my information at any point of the study.

I understand that taking part in this study is voluntary (my choice) and that I may withdraw from the testing at any time and this will in no way affect my *academic progress/ employment.*

I understand that my participation in this study is confidential and that no material which could identify me will be used in any reports on this study.

I have had time to consider whether to take part, and know who to contact if I have any questions about the study.

I agree to take part in this research.

	Yes	**No**
I consent to my interview/activity being videotaped/audiotaped		
I wish to receive a summary of the results		

Signed: ____

Name: ____

Signature of Research Participant's Support Person (if applicable)

____

Date: _______________________

Witness: ____

I/We as researcher(s) undertake to maintain the confidentiality of information gather during the course of this research.

Signed____

Dated________________________

This study has been approved by the <<ethics committee>> on <<date>>, Reference # << >>.