An investigation into the effect of unilateral immobilisation of the upper limb on the physiological responses to stair climbing.

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Declaration

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This Thesis/Dissertation/Research Project entitled an investigation into the effect of unilateral immobilisation of the upper limb on the physiological responses to stair climbing is submitted in partial fulfilment for the requirements for the Unitec degree of Master of Osteopathy.

CANDIDATE’S DECLARATION

I confirm that:

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

Research Ethics Committee Approval Number: 2008 - 862

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Abstract

Introduction: Musculoskeletal conditions or injuries to the shoulder are frequently seen within primary healthcare practice, with a number of these complaints resulting in restricted joint mobility. It is known that minor restrictions to movement, particularly those that disrupt the normal gait cycle, result in an increased energy demand. Though previous studies have not demonstrated any increase in energy demand during a level walking task with an immobilised upper limb, the extent to which upper limb immobilisation during stair climbing has on physiological outcomes has yet to be determined.

Purpose: The objective of this study was to measure the effect of unilateral restriction of upper limb on energetic cost of stair climbing.

Methods: Thirty four participants, 16 males (age 28 ± 9 years, height 181 ± 6cm, weight 75 ± 13kg) and 18 females (age 23 ± 4 years, height 170 ± 5cm, weight 64 ± 6kg) ascended a public access staircase at a rate of 80 steps.min\(^{-1}\) for five minutes and fifteen seconds over two experimental trials. Participants were randomly assigned to conduct the trial with complete mobility, followed by immobilisation of the dominant (n=17) or non-dominant (n=17) upper extremity, or vice versa. Outcome measures of oxygen uptake (mL.kg\(^{-1}\).min\(^{-1}\)), total energy cost (kcal.d\(^{-1}\)), relative energy expenditure (kcal.d\(^{-1}\).kg\(^{-1}\)) and heart rate (beats.min\(^{-1}\)) were recorded and utilised in data analysis, relating to pre- (0 minutes 0 seconds) versus post- (5 minutes 15 seconds) the experimental time both within and between the groups (immobilised and non-immobilised).

Results: Post stair climb data shows only a trivial to small difference in the physiological measures of the non-immobilised and immobilised groups (oxygen uptake; 1.4 ± 0.5 and 1.4 ± 0.4mL.min\(^{-1}\).kg\(^{-1}\), heart rate; 58 ± 16 and 59 ± 16beats.min\(^{-1}\), total energy cost; 9858 ± 3560 and 10499 ± 3062kcal.d\(^{-1}\), and relative energy expenditure 139 ± 42 and 149 ± 39kcal.d\(^{-1}\).kg\(^{-1}\), respectively). A trivial to small difference in the physiological measures in the two groups prior to the stair climb task (oxygen uptake; 0.5 ± 0.2 and 0.5 ± 0.2mL.min\(^{-1}\).kg\(^{-1}\), heart rate; 103 ± 19 and 106 ± 14beats.min\(^{-1}\), total energy cost; 3711 ± 1555 and 3362 ± 1419kcal.d\(^{-1}\), and relative energy expenditure 53 ± 23 and 48 ± 21kcal.d\(^{-1}\).kg\(^{-1}\), respectively) and a large difference pre- to post- the stair climbing task in the outcome measures was observed. Additional analysis
demonstrates only a trivial to small difference in the physiological measures between order of immobilisation, and between immobilisation of the dominant or non-dominant upper limb.

**Conclusion:** Immobilisation of the upper limb had only a trivial to small effect on oxygen uptake, heart rate, total energy cost, and relative energy expenditure during a stair climbing task.

**Keywords:** arm swing; metabolic cost; locomotion; heart rate; energy expenditure; oxygen uptake; oxygen kinetics.
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Chapter one

Literature Review

Introduction

In 2004, the Accident Compensation Corporation New Zealand documented that shoulder injuries were the third most common musculoskeletal complaint in general practice clinics, which included medical practitioners, physiotherapists and osteopaths (Accident Compensation Corporation, 2004). These injuries often result in restriction of normal shoulder range of movement or immobilisation of the upper limb by a sling. Minor restrictions to movement, such as those imposed by a sling, may disrupt normal gait and alter the efficiency of the musculoskeletal system, therefore imparting a greater metabolic cost (Greenman, 1996, p. 11). Based on the hypothesis stated by Greenman (1996) the objective of this study was to model a musculoskeletal system dysfunction by imposing a unilateral restriction of upper limb movement to observe the physiological responses to a stair climbing task.

The aim of this review is to provide a brief overview of the literature pertaining to upper limb joint restriction during stair climbing. In particular, the biomechanics of joint restriction and consequent physiological effects were of interest. Literature for this review was sourced primarily from databases (Medline, SPORTDiscus, PubMed and ScienceDirect), Google Scholar, and textbooks using the following keywords; immobilisation, locomotion, stair climbing, upper limb, arm swing, gait and energy expenditure.

This search lead to the identification of the key themes for discussion. The review of literature is set out in three parts. Section one introduces the biomechanics of stair climbing in relation to lower and upper limb movement. Section two discusses the physiological responses to an exercise task. Section three outlines the importance of physical activity and exercise and how stair climbing is a beneficial form of exercise.
Finally section four discusses the physiological and biomechanical changes in the lower and upper limb following immobilisation during both level walking and stair climbing, leading into a conclusion and the study objective.
1. Biomechanics of Stair Climbing and Locomotion in the Lower and Upper Limb

1.1 Lower limb

1.1.1 Stair climbing versus level walking

Stair climbing is a modified form of level walking (Trew & Everett, 2005, p. 185). Compared to level walking, stair climbing requires an increased joint range of motion, particularly at the hip and knee, and involves increased muscular activity to generate forces that vertically translate the body’s centre of gravity (Andriacchi, Andersson, Fermier, Stern, & Galante, 1980; Trew & Everett, 2005, p. 185). Stair climbing is potentially a more biomechanically and physiologically challenging task than level walking as the individual has to work against gravity to ascend to the next step (Protopapadaki, Drechsler, Cramp, Coutts, & Scott, 2007).

1.1.2 Phases of stair climbing

1.1.2.1 Stance phase

The stance phase is where one foot is in contact with the ground while the other foot is in the swing phase. Stance phase is partitioned into weight acceptance, pull up and forward continuation of movement (McFayden & Winter, 1988). On contact with the step, weight is typically placed on the anteriomedial third of the foot and then transferred throughout the whole foot (McFayden & Winter, 1988; Trew & Everett, 2005, p. 186). Once the body weight is transferred through the foot, the ankle is dorsiflexed while the hip and knee joints are flexed (Andriacchi, et al., 1980; Reiner, Rabuffetti, & Frigo, 2002). Concentric contraction of the hip extensors (gluteus maximus and the posterior fibres of gluteus medius and minimus muscles), knee extensors (rectus femoris, vastus medialis, vastus intermedius and vastus lateralis), and the ankle plantarflexors (soleus, gastrocnemius, tibialis posterior and plantaris) pull the body’s centre of gravity superiorly, lifting the rear foot off the ground into the single stance phase (McFayden & Winter, 1988). The single stance phase is where only one foot is in contact with the stepping surface. Consequently, there is a greater potential risk of falling during this phase, making sound balance essential (Trew & Everett, 2005, p. 186). During this
single stance phase, the hip abductor muscle group, primarily gluteus medius, is active to stabilise and prevent the pelvis from dropping to the unsupported side (McFayden & Winter, 1988). Forward continuation of movement is maintained by the hip and knee extensor muscles. Activation of the quadriceps muscle group maintains knee joint position, while the ankle plantarflexes to propel the limb into the swing phase.

1.1.2.2 Swing phase
Swing phase refers to the foot that is not in contact with the ground and is moving to the next step. This phase is partitioned into simultaneous foot clearance and lifting of the swinging limb and foot placement (McFayden & Winter, 1988). Foot clearance and lifting of the swinging limb act to move the limb past the immediate step and onto the next step. This movement is achieved initially by concentric contraction of the tibialis anterior muscle to dorsiflex the ankle, followed by the hamstrings muscle group to flex the knee joint and the iliopsoas muscle to flex the hip joint to pull the leg onto the next stair. Concurrently, eccentric contraction of the quadriceps muscle group occurs to control any unwanted knee flexion. A greater degree of concentric than eccentric muscular activity (in stair ascension) results in excessive hip and knee flexion causing the swinging limb to move much higher than the step before foot placement. Foot placement is controlled by eccentric activity of the hip flexors, primarily the iliopsoas muscle, to allow the hip to extend, lowering the limb to make contact with the next step (Andriacchi, et al., 1980; McFayden & Winter, 1988). Throughout the swing phase, tibialis anterior contracts to maintain ankle dorsiflexion required for step clearance, and works eccentrically before foot placement to control ankle plantarflexion to meet the step in preparation for weight bearing (Andriacchi, et al., 1980; McFayden & Winter, 1988).

1.2 Upper limb
1.2.1 Role of the upper limb during locomotion
Upper limb movement occurs primarily within the four joints of the shoulder (glenohumeral, acromioclavicular, sternoclavicular and scapulothoracic) and to a lesser degree of movement occurring at the elbow joint (Trew & Everett, 2005, p. 175). The importance of the upper limb during locomotion is that it acts as a rhythmic pendulum,
moving in an anti-phase to the striding lower limb (Grimshaw, Lees, Fowler, & Burden, 2007, p. 252) and provides a counterbalance to lower limb movement (Hanada & Kerrigan, 2001; Kapandji, 1987, p. 184).

Upper limb movement during locomotion is divided into forward (flexion) and backward (extension) swinging motions. Fernandez Ballesteros, Buchthal & Rosenfalck (1965) state that the forward swinging action is driven passively by momentum, as they demonstrated little electromyographic activity in the primary flexor muscles of the shoulder (the anterior deltoid and the clavicular part of pectoralis major). Initiation and movement into extension is controlled by the primary shoulder extensor muscles (middle and posterior deltoid, lattisimus dorsi, and teres major), with both supraspinatus and trapezius muscles active throughout the forward and backward swing (Fernandez Ballesteros, et al., 1965; Norkin & Levangie, 1992, p. 86). To ensure adequate trunk clearance of the swinging arm, muscular activity occurs in the shoulder abductor muscles of the middle deltoid, pectoralis major, subscapularis, teres major, and lattisimus dorsi (Fernandez Ballesteros, et al., 1965; Kapandji, 1987, p. 185).

Fernandez Ballesteros et al. (1965) and Li, Wang, Crompton & Gunther (2001) demonstrated that muscular activity within the upper limb continues even when movement of the arm is restricted. Continuation of muscular activity in a restricted upper limb was conceptualised by Gray (1944) as a neurally driven activity that has been retained from when our forearms were used to locomote. Upper limb movement during locomotion is an integral part of the dynamics of movement, essential in generating smooth, non-jerky movement (Jackson, 1983; Jackson, Joseph, & Wyard, 1978; Li, et al., 2001). Jackson, Joseph & Wyard (1983a) and Jackson, Joseph & Wyard (1983b) concluded that activation of a central motor pattern and muscular control of the upper limb occur concurrently and seem to be the most likely reasons for retention of upper limb movement.
2. Physiological Responses to Exercise

The cardiorespiratory responses of cardiac output, blood pressure, and oxygen consumption increase in response to performing physical exercise in order to supply adequate oxygen and nutrients to exercising skeletal muscle (Laughlin, 1999; Widmaier, Raff, & Strang, 2004, p. 141). These responses are controlled, in part, by chemical changes systemically (peripheral skeletal musculature and vasculature) that activate baroreceptors and muscle chemoreceptors (McCloskey & Mitchell, 1972). In addition, central command centres control the cardiovascular responses in anticipation of exercise and during activity (Green, et al., 2007; Widmaier, et al., 2004, p. 145). Performing physical exercise also imparts a metabolic cost on the individual that varies between differing exercise modalities and intensities.

2.1 Influence of exercise on cardiac output

In order to meet oxygen demand in exercising skeletal muscle, cardiac output increases to provide a greater amount of oxygenated blood. This increase is mostly due to a rise in heart rate as stroke volume reaches a plateau and possibly diminishes towards the upper end of exercise intensity. The increase in heart rate is mediated by several factors such as regulation by the autonomic nervous system (Wilmore, Costill, & Kenney, 2008, p. 79), influence of catecholamines and other factors such as age, gender and temperature.

During exercise, the autonomic nervous system changes the balance between the sympathetic and parasympathetic systems resulting in an increased sympathetic and decreased parasympathetic activity (Bray, Cragg, Macknight, Mills, & Taylor, 1986, p. 101). Increased sympathetic activation occurs partly as a result of chemical changes (such as increases in hydrogen concentration, blood lactate concentration, carbon dioxide content and reduction in oxygen availability) within the systemically that are detected by muscle chemoreceptors. Afferent signals are then transmitted to the medullary cardiovascular centre, comprised of an inhibitory and acceleratory centre. If the cardioacceleratory centre is stimulated impulses are sent along the thoracic spinal cord and sympathetic accelerator nerves to the sinoatrial node, atroventricular node, heart
muscle, and coronary arteries (Marieb, 2004, p. 625). These nerves release the catecholamine noradrenaline onto the β-adrenergic receptors of the heart. Stimulation of these receptors by noradrenaline promotes the sympathetic response of an increased in the force of cardiac myocyte contraction and an increased heart rate that leads to an increase in cardiac output (Bray, et al., 1986, p. 104; Klabunde, 2005, p. 56; Widmaier, et al., 2004, p. 151). If the cardioinhibitory centre is activated a parasympathetic response predominates subsequently decreasing heart rate. Stimulation of this centre sends impulses to the dorsal motor nucleus of the vagus nerve within the medulla, which in turn sends inhibitory signals to the heart via branches of the vagus nerve terminating in the heart muscle wall, sinoatrial and atrioventricular nodes.

Catecholamines, such as adrenaline and noradrenaline have a chemical influence on cardiac output during exercise. In response to stimulation of the sympathetic nervous system, adrenaline is liberated from the adrenal medulla and noradrenaline is released from the sympathetic nerves. These catecholamines cause an increase in heart rate and consequently cardiac output to prepare the individual for physical activity or to facilitate current physical activity (Guyton & Hall, 2000, p. 110).

It is well established that maximum heart rate declines with age (Marieb, 2004, p. 628), and that females have a slightly faster average resting heart rate than men (Gillum, 1988). Alterations in resting heart rate with age are not as clear (Fogari, et al., 1997). An increase in body temperature, for example during exercise or fever, causes an increase in heart rate and a temporary increase in the contractile strength of the heart (Guyton & Hall, 2000, p. 112). These effects are thought to occur as an increase in temperature causes an increased permeability of the cardiac muscle to controlling ions (potassium and calcium) that increase the hearts self-excitation process (Guyton & Hall, 2000, p. 112).

2.2 Influence of exercise on blood pressure and redistribution of blood flow

Blood pressure response to upright aerobic exercise is a progressive increase in systolic pressure with a maintenance or slight decrease in diastolic pressure (Kelley & Kelley, 2000). The increase in systolic pressure is due to the increase in cardiac output that
increases as a consequence of an increase in heart rate. The slight decrease in diastolic blood pressure, however, is primarily due to peripheral vasodilatation that occurs during exercise as blood moves away from the capillaries to the skeletal muscle (Bray, et al., 1986, p. 89). This normal response may change in older patients, those with an underlying cardiovascular condition, or patients on certain medications (Protogerou, et al., 2007).

The normal response to an increase in energy demand by skeletal muscles during exercise is a vasoconstriction in the arterioles and capillaries leading to and surrounding tissues that require minimal blood supply to function (such as the kidney and digestive organs). In contrast, vasodilation occurs in the vasculature leading to and surrounding tissues demanding greater blood flow. This vasodilation occurs in exercising skeletal muscle to provide the oxygen required for energy production, in the coronary circulation to increase the amount of oxygenated blood to the heart muscle, and in the skin to allow heat dissipation. Cerebral blood flow remains relatively unchanged.

2.3 Influence of exercise on oxygen consumption

Various metabolic pathways produce the energy required to complete an exercise task. At rest, or light to moderate intensity exercise lasting approximately ten minutes to several hours, 90 to 95% of the energy demands are met by the process of aerobic glycolysis, a sequence of cellular, chemical reactions to hydrolyse glucose in the presence of oxygen (Bray, et al., 1986, p. 90; Klabunde, 2005, p. 99; Marieb, 2004, p. 774). This process culminates in a relatively high adenosine triphosphate (ATP) yield. In order to generate sufficient ATP aerobically, oxygen needs to be delivered to and utilised by the skeletal muscle mitochondria (Tschakovsky & Hughson, 1999). The remaining (5 to 10%) energy yield is met by the phosphorylation of stored substrates (such as phosphocreatine or glucose when oxygen is in insufficient supply) or the hydrolysis of ATP.

Utilisation of oxygen during exercise can be represented in three stages. The initial, cardiodynamic phase (I) represents the oxygen exchange occurring within the first few
breaths during exercise and is associated with increased pulmonary blood flow due to an increase in cardiac output (Jones & Poole, 2005, p. 14). The second, fast phase (II) represents deoxygenated blood leaving exercising musculature and travelling via the heart to the lung. The rate at which oxygen uptake increases over time during the non-steady state phases (I and II) depicts the ability of the circulatory system to deliver oxygen, the cells to utilise oxygen, and the venous system to return blood to the lungs ready for reoxygenation (Jones & Poole, 2005, p. 15).

The third, steady state phase (III) corresponds to the point at which carbon dioxide plateaus and venous oxygen content reaches its lowest point during moderate intensity exercise (Jones, Koppo, & Burnley, 2003, p. 15). Steady state oxygen uptake (phase III) is normally reached within two to three minutes in moderate intensity exercise (Jones, et al., 2003; Jones & Poole, 2005, p. 16; Whipp & Wasserman, 1972). At higher exercise intensities, attainment of a steady state may be delayed for up to 15 minutes (Henry & DeMoor, 1956; Jones & Poole, 2005, p. 15; Whipp & Wasserman, 1972) or completely absent (Poole, Ward, Gardner, & Whipp, 1988; Roston, et al., 1987; Whipp, 1987). Indeed, there is considerable debate as to whether a ‘true’ maximum oxygen uptake is ever reached (Hill, Long, & Lupton, 1924; Noakes, 2000).

2.4 Influence of exercise on metabolic energy expenditure

Energy is expended in order to maintain essential body functions such as breathing and heart rate, for tissue growth and repair, and to allow the ability to perform physical activity. To reduce the metabolic cost on the individual, there is an evolutionary tendency to minimise the degree of energy expended during everyday tasks (Sparrow, 2000, p. 13). Therefore, frequently conducted tasks, such as walking or talking, are associated with minimal metabolic costs. On the other hand, skilled movements or high intensity/duration muscular activities, require a greater degree of muscular activation. Further, the metabolic cost associated with a task could be minimised if the individual becomes more practised or ‘skilled’ at the task (Sparrow & Newell, 1998). Sparrow (2000, p. 14) showed that the level of muscular activation during movement is positively correlated with metabolic energy expenditure.
Greenman (1996, p. 11) discussed how the musculoskeletal system is a major expender of total body energy. Increased activity of the musculoskeletal system during physical activity places a greater demand upon the internal viscera to develop and deliver the energy required to perform the exercise. Greater demand results in a greater degree of energetic cost. If the efficiency of the musculoskeletal system is compromised by dysfunction, particularly if normal gait is not preserved, a greater energetic cost occurs. This greater cost is incurred not only during physical activity, but for daily physical activity as well.
3. Importance of Physical Activity and Exercise in the Maintenance of Health

The 2006/7 New Zealand Health Survey showed only half of all New Zealand adults were regularly physically active, completing at least 30 minutes of physical activity per day on five or more days of the last week. Further, 15% of adults reported being involved in less than 30 minutes of exercise in the last week (Ministry of Health, 2008).

Encouraging and incorporating physical exercise into day to day activity would have considerable health benefits for both the individual and the population as a whole (Ministry of Health, 2008). An increased level of physical activity has shown to be protective against heart disease (Berlin & Colditz, 1990; Ignarro, Balestrieri, & Napoli, 2007), type II non-insulin dependent diabetes (Burr, Rowan, Jamnik, & Riddell, 2010) and certain forms of cancer (colon (Colditz, Cannuscio, & Frazier, 1997), post-menopausal breast (Schmidt, et al., 2008), lung and endometrial (Friedenreich, 2001)). Exercise also helps to lower blood pressure, which is a risk factor for heart disease and type II diabetes (Whelton, Chin, Xin, & He, 2002). Further, in populations greater than 45 years of age, a quarter of type II diabetes cases and half the number of hip fractures could be avoided with appropriate exercise (Whitehead, 1995).

Based on the numerous health benefits of regular physical activity and the findings of the 2006/7 New Zealand Health Survey, Sport and Recreation New Zealand’s PushPlay scheme was developed to inspire the nation to become more active. PushPlay recommends at least 30 minutes a day of moderate intensity physical activity on most days of the week, which can be cumulative over the course of the day. Sport and Recreation New Zealand (2008) PushPlay website lists the first quick tip for becoming active as ‘taking the stairs instead of the lift’, indicating stairs as an easy, ever-present form of exercise with numerous health benefits.

3.1 Stair climbing as exercise

Stair climbing is a beneficial form of exercise that has been shown to improve cardiovascular fitness (Boreham, Wallace, & Nevill, 2000; Fardy & Ilmarinen, 1975;
Ilmarinen, et al., 1979; Loy, et al., 1994), reduce cholesterol levels (Boreham, et al., 2000), reduce percentage body fat (Fardy & Ilmarinen, 1975), and has a positive association with bone mineral density (Coupland, et al., 1999). Based on the study findings by (Bassett, et al., 1997) and Teh & Aziz (2002), stair climbing requires almost 10 times greater energy expenditure than at rest and is therefore considered as moderate to vigorous exercise. In addition, stair climbing has been suggested as a beneficial form of exercise due to its presence at most places of residence or employment, that it does not incur any monetary cost (Teh & Aziz, 2002), and that it is a more physiologically and biomechanically challenging task than normal walking (Eves, Webb, & Mutrie, 2006; Protopapadaki, et al., 2007).
4. **Physiological and Biomechanical changes during Stair Climbing and Immobilisation**

4.1 **Physiological and biomechanical changes within the lower limb during stair climbing**

Greenman (1996, p. 11) states that movement restriction in one of the major joints in the lower limb can increase the energetic cost of normal walking by up to 40% and up to 300% if two joints are restricted. As stair climbing requires greater muscular activity than level walking (Andriacchi, et al., 1980), it is assumed that the energetic cost of stair climbing with a lower limb dysfunction would be considerable. Numerous studies, such as those by Andriacchi, Galante & Fermier (1982); Bergmann, Graichen and Rohlmann (1995); Powers, Boyd, Torburn, & Perry (1997); Thambyah, Thiagarajan, & Goh Cho Hong (2004) and Asay, Mündermann & Andriacchi (2008) to name a few, have been conducted to demonstrate how biomechanical changes in the lower limb influence the individual’s ability to climb stairs. The works of all the aforementioned authors investigated the influence of hip or knee dysfunction, either due to an injury, surgery or degenerative process, on the individual’s ability to ascend stairs. These studies showed that dysfunction within a given lower limb resulted in a greater degree of muscular work and power output by either the contralateral or ipsilateral lower limb. The dysfunctional change also results in slower stair climbing rates (Powers, et al., 1997), active adaptation of joint positioning (Thambyah, et al., 2004), and compensatory changes in the contralateral and ipsilateral hip, knee, and/or ankle joint angles (Asay, et al., 2008; Powers, et al., 1997).

4.2 **Physiological changes occurring following immobilisation of the upper limb**

Only a few studies have observed the effect of restricting upper limb movement on the energetics of level locomotion. No known studies have investigated this effect during stair climbing. The earliest technical report by Chapman & Ralston (1964) investigated the energetic cost of level walking when an upper and/or lower limb were restricted. Chapman and Ralston (1964) showed no ‘statistically significant change’ in energy expenditure when upper limb movement was restricted. The results of this initial study have been replicated by Park, Shin & Kim (2000) and Hanada & Kerrigan (2001) who
demonstrated that during level walking at slower walking speeds (of 1.1 and 1.2m.s\(^{-1}\)) when normal movement of an upper limb was immobilised, there was a trivial difference in energy expenditure. However, further studies by Park et al. (2000) and Umberger (2008) at greater walking speeds of 1.3 to 1.7m.s\(^{-1}\), demonstrated a respective increase in energy expenditure from 2.9 ± 0.2 to 3.1 ± 0.2W.kg\(^{-1}\) (at p=0.004) and from 12.1 ± 2.5 to 12.8 ± 2.7L.kg\(^{-1}\).min\(^{-1}\) when an upper limb was immobilised.

### 4.2.1 Significance of upper limb immobilisation to the osteopathic profession

In 2004, the Accident Compensation Corporation New Zealand found that shoulder injuries were the third most common musculoskeletal complaint in general practice, physiotherapy and osteopathic clinics (Accident Compensation Corporation, 2004). A number of shoulder injuries can lead to restricted movement of the upper limb, including a recent shoulder dislocation, surgery, an acromioclavicular joint injury, or a musculoskeletal condition such as adhesive capsulitis or supraspinatus tendonitis. As patients with these injuries are frequently discharged from care with an arm immobilised by a sling and due to the reasonably common occurrence of shoulder complaints, osteopaths in practice are often met by patients who have restricted movement of an upper limb. Though healthy individuals can perform physical tasks such as climbing stairs rather easily, the task becomes more demanding when normal limb movement is restricted (Reiner, et al., 2002). This increased demand may hinder the participant’s ability to perform daily physical tasks and to exercise (Greenman, 1996, p. 11) and compromise the patients ability to maintain health.
5. Conclusion

Greenman (1996, p. 11) states if a musculoskeletal dysfunction alters the efficiency of normal gait this has a detrimental effect on total body function in regards to metabolic demand. This has indeed shown to be true for the larger joints of the hip (E. Mattsson, 1989; Waters, Barnes, Husserl, Silver, & Liss, 1988), knee (Abdulhadi, Kerrigan, & LaRaia, 1996; Hanada & Kerrigan, 2001; Eva Mattsson & Brostrom, 1990) and ankle (Eva Mattsson & Brostrom, 1990). As movement of the upper extremity has been shown to be an essential component of efficient, non-jerky locomotion (Jackson, 1983; Jackson, et al., 1983a; Li, et al., 2001), the hypothesis of Greenman (1996, p. 11) should hold true for restrictions to upper extremity movement. Though, previous studies into the energetic cost of level walking with an immobilised upper extremity have failed to find any increase in energetic cost when an individual’s upper extremity is immobilised (Chapman & Ralston, 1964; Hanada & Kerrigan, 2001; Park, et al., 2000). What has yet to be identified is if the energetic cost is influenced by immobilisation of an upper limb whilst conducting an every-day task of stair climbing. From this, the objective of the study was to observe if immobilisation of an upper limb influenced the physiological responses to stair climbing when compared to normal upper limb movement.
Chapter two

Manuscript

1. Introduction

A report by the Accident Compensation Corporation of New Zealand (2004) revealed that musculoskeletal complaints regarding the shoulder were the third most common compliant presenting to a general practice, physiotherapy or osteopathic clinic. These injuries often result in restriction of normal shoulder range of movement or immobilisation of the upper limb by a sling. Greenman (1996, p. 11) states that any minor restrictions to movement may disrupt the normal gait cycle and alter the efficiency of the musculoskeletal system, therefore imparting a greater metabolic demand.

It has been demonstrated that upper limb movement is an integral part of the dynamics of normal locomotion (Eke-Okoro, Gregoric, & Larsson, 1997; Fernandez Ballesteros, et al., 1965; Jackson, et al., 1983a, 1983b; Li, et al., 2001). Chapman & Ralston (1964), Park, Shin & Kim (2000), and Hanada & Kerrigan (2001) understood the essential role that the upper limb plays during movement and conducted research to demonstrate if restricting upper limb movement during level walking imparted a greater energetic cost on the individual. Chapman & Ralston (1964), Park et al. (2000), and Hanada & Kerrigan (2001) found that restriction of the upper limb during level walking had no effect on total energy cost when compared to unrestricted walking. However, the extent to which upper limb immobilisation during stair climbing has on metabolic cost has yet to be determined.

Based on the hypothesis of Greenman (1996, p. 11) and the lack of evidence regarding the physiological responses of immobilisation during a stair climbing task, the objective of this study was to model a musculoskeletal system dysfunction by imposing a unilateral restriction of upper limb movement.
2. Methods

Participants
Thirty four participants, 16 males (age 28 ± 9 years, height 181 ± 6cm, weight 75 ± 13kg) and 18 females (age 23 ± 4 years, height 170 ± 5cm, weight 64 ± 6kg) responded to recruitment posters placed on public notice boards around the Unitec campus (Auckland, New Zealand). The sample size was determined using computer software ("G*Power," 2008) in which the following assumptions were made: alpha level of 0.05, 80% power at a Type II error, and a moderate (0.5) effect size. To be included in the study the participants had to be between 18 and 50 years of age, be walking more than one flight of stairs at least once a week as part of their everyday activity, be pain-free during walking and have no current, or recent history of shoulder complaint or injury. Participants were excluded from the study if they had a history of a cardiovascular or respiratory disorder, thrombosis, asthma that required hospitalisation within the last five years, or a gait, rheumatological or upper motor condition. Meeting these criteria was initially discussed on the first contact with the researcher and further confirmed using a health screening questionnaire at the beginning of the experimental trial.

Apparatus
The physiological outcome measures of oxygen uptake (L.kg⁻¹.min⁻¹), total energy cost (kcal.d⁻¹), and relative energy expenditure (kcal.d⁻¹.kg⁻¹) were captured using the Cortex Metamax 3B cardiopulmonary exercise system (CORTEX Biophysik, Leipzig, Germany) (Figure 1). Heart rate (beats.min⁻¹) was captured using a Polar heart rate monitor (Polar T31 Transmitter, Polar NZ, Auckland, New Zealand). The data were transferred to and stored within the Metasoft software programme (Figure 2). The Metamax 3B system consisted of a breathing mask with an attached turbine and gas sampling line to determine the breathing frequency, breath-by-breath oxygen consumption and carbon dioxide production. The Metamax 3B oxygen and carbon dioxide analysers are accurate to 0.1% volume, based on the manufactures’ specifications. The oxygen and carbon dioxide analysers were calibrated prior to every trial session based on the manufactures’ recommendation.
The participant’s age, gender, height, weight, level of physical activity (in hours/week) and the size of the breathing mask used were entered into the Metasoft programme. These parameters enabled the software to calculate the dead space volume of the breathing mask, which were then used in the calculation of total energy cost and relative energy expenditure. An arm sling (Model number OPP3089, size Medium, Auckbritt, Auckland) was used to restrict movement of the participant’s upper limb during their immobilised stair climbing trial (Figure 3). A portable media player was worn by each participant that played an audio track of a metronome at a rate of 80 beats.min\(^{-1}\) running for 5 minutes and 15 seconds.

[Insert Figure 1 here]

[Insert Figure 2 here]

[Insert Figure 3 here]

*Experimental Design*

The experiment was conducted in a 30-storey building in Auckland City, with appropriate permission from the Facilities Manager of Kiwi Income Property Trust. Ethical approval was obtained from the Unitec Research Ethics Committee (UREC). All participants provided written formal consent to participate.

Each participant ascended the stairs at a rate of 80 steps.min\(^{-1}\). This stepping rate is based on similar previous studies by Boreham et al. (2000) and Teh & Aziz (2002) who found participant-selected brisk, yet comfortable walking paces during stair ascension of 80 and 95 steps.min\(^{-1}\), respectively.

It is well known that steady state oxygen consumption is reached in approximately three minutes during a moderate intensity exercise task (Jones & Poole, 2005; Whipp & Wasserman, 1972). Therefore, the experimental trial was conducted over a slightly
longer time period of 5 minutes and 15 seconds to ensure steady state oxygen consumption was reached for each participant.

Before conducting the experiment, participants were given verbal and written instruction regarding the events of the experiment and were asked to complete a health screening questionnaire. Each participant ascended the stairs twice, once with complete mobility and once with normal upper limb movement restricted by a sling. The order of testing (immobilised group or non-immobilised group) and immobilisation of the dominant or non-dominant arm was randomly assigned among participants to prevent selection bias. This was done by allocation into either group by order of arrival to the experimental base. The heart rate monitor, breathing mask and portable media player were then placed on the participant. The participant stood at rest for approximately two minutes whilst the Metamax 3B system analysed the ambient temperature, atmospheric oxygen and carbon dioxide concentrations. Once completed, the participant was guided to the staircase. Before climbing, the participants were instructed to keep to the time of the metronome and that they could not stop or use the handrails. The metronome track was played and the participant began climbing the staircase accompanied by the researcher. On conclusion of the metronome track, the participant pressed the play/pause button on the Metamax 3B system to indicate they had reached the end of their experimental trial. The participant then climbed back down the stairs to the experimental base. Over the course of the 5 minutes and 15 seconds, data were sent from the Metamax 3B system to the Metasoft programme via telemetry and was saved at the conclusion of each participants trial.

The trial was repeated with either the participants dominant (n=17) or non-dominant (n=17) upper limb immobilised. To immobilise the arm, the participant’s arm was placed in a triangular sling, holding the shoulder in neutral flexion/extension, adduction and internal rotation, and the elbow at 90° of flexion. Between each trial, the participant was given between 15 and 45 minutes to rest so that monitored measures could return to resting levels.
Data Management

Over the course of each trial the Metamax 3B system randomly sampled the four outcome measures of oxygen uptake (L.kg⁻¹.min⁻¹), total energy cost (kcal.d⁻¹), relative energy expenditure (kcal.d⁻¹.kg⁻¹) and heart rate (beats.min⁻¹), within each participant and between participants, in a non-uniform time course. This scenario was somewhat problematic and could not be adjusted. As a consequence, data analysis related only to average pre- (0 minutes 0 seconds) versus average post- (5 minutes 15 seconds) the experimental time, and the difference between the two values.

Individual data for each variable and for each group (immobilised and non-immobilised) can be found in Appendix 1. From the individual data, the times to reach half end-point values across the outcome variables in both the immobilised and non-immobilised groups were calculated.

Data values are expressed as means ± standard deviation. Differences between groups and over time were expressed as multiples of a standard deviation (Effect Size). Precision of the estimates were expressed using 95% confidence limits and the clinical likelihoods of differences were expressed using a percent probability (Hopkins, 2009). Magnitudes of effect were interpreted according to the criteria of Cohen (1988, p. 71) and Hopkins (2009) in which effect sizes less than 0.2, from 0.2 to 0.49, from 0.5 to 0.69, and greater than 0.7 were regarded as trivial, small, moderate, and large respectively.

Statistical Analysis

Microsoft Excel software was used for collation of data and statistical analysis. Paired t-tests were computed for each variable between groups prior to the stair climb, within each group pre- to post-stair climb, and between groups for the overall change score (pre-to post-stair climb). Further, paired and unpaired t-tests were computed to determine if order of immobilisation or immobilised upper limb (dominance) had an influence on the results. The author did not adjust the confidence limits so as to hold the overall Type O error rate to 5%, the chance that any true value in this study falls outside its confidence interval (Hopkins, 2009). The author is of the opinion that, in publishing precision of
estimates, controlling error rate is not an issue. Readers should interpret reported effects by being aware that the population value may be outside the confidence interval for some of the effects.
3. **Results**

All of the 34 participants who initially enrolled in the study completed the experimental trial. However, one participant was excluded from data analysis due to non-compliance in regards to stepping rate during the experimental trial.

A *large* difference is seen pre- to post- stair climb in both the immobilised and non-immobilised groups across all four outcome measures. These data are shown in **Table 1**.

[Insert Table 1 here]

A *trivial* to *small* difference in the immobilised and non-immobilised groups prior to the stair climbing task is observed in all four outcome measures. These data are shown in **Table 2**.

[Insert Table 2 here]

A *trivial* to *small* difference is observed across all four outcome measures post- stair climb in the immobilised and non-immobilised groups. These data are shown in **Table 3**.

[Insert Table 3 here]

The physiological measures of oxygen uptake, heart rate, total energy cost and relative energy expenditure were on average higher in approximately half of the participants in the second trial when compared to the first. A 5% average increase in heart rate, total energy cost and relative energy expenditure and an 8% average increase in oxygen uptake can be seen during the second stair climbing task when compared to the first stair climbing task. This indicates that work load was higher in the second trial compared to the first. Analysis was conducted to investigate if the order of immobilisation had any effect on the outcome measures. This analysis shows that there is only a *trivial* to *small effect* of order of immobilisation on the four outcome measures. These data are shown in **Table 4**.
Immobilisation of the dominant or non-dominant limb was not standardised between participants. The data does not demonstrate considerable differences in the means or greater mean values across one condition (dominant or non-dominant) in any of the four outcome measures (oxygen uptake; 24 ± 5L.kg\(^{-1}\).min\(^{-1}\) and 25 ± 2L.kg\(^{-1}\).min\(^{-1}\), heart rate; 155 ± 13beats.min\(^{-1}\) and 150 ± 18beats.min\(^{-1}\), total energy cost; 12900 ± 3200kcal.d\(^{-1}\) and 12000 ± 1600 kcal.d\(^{-1}\), and relative energy expenditure; 171 ± 37 kcal.d\(^{-1}\).kg\(^{-1}\) and 179 ± 14 kcal.d\(^{-1}\).kg\(^{-1}\) for dominant and non-dominant respectively). Therefore statistical analysis was conducted to consider if immobilisation of the dominant verses the non-dominant upper limb had any effect on the outcome measures. This analysis demonstrates that there is only a trivial to small difference between the groups. When the dominant arm is immobilised, the outcome measures are only slightly higher than the non-dominant arm data. These data are shown in Table 4.

[Insert Table 4 here]

On observation of the individual results, it appears that for the majority of the participants the second stair climbing trial, irrespective of whether that the upper limb was immobilised or non-immobilised was metabolically more challenging across all observed outcome measures. Plots of these data can be seen in Appendix 1. Participants A to R conducted the immobilised trial second and the values over the four outcome measures are higher than the non-immobilised task. This increase may be due to the fact that it is the second stair climbing task rather than the immobilisation itself. Consistent with this, participants S to HH performed the non-immobilised trial second, showing higher values in the non-immobilised data sets across the four outcome measures. For a few of the participants, the difference between the immobilised and non-immobilised data sets is either hard to distinguish, or mean increases or decreases are not seen over all four outcome measures.

In contrast, four individuals show an increase across all four outcome measures during their first stair climbing trial. For example, participant R found it more metabolically challenging over all the observed outcome measures to perform the first non-immobilised
trial than the subsequent immobilised trial. Further, participants U, EE and GG exhibited an increase in each of the four outcome measures during their immobilised trial compared with the subsequent non-immobilised trial. Plots of these data can be seen in Appendix 2.

Some individuals show a lag, or delay, in the time it took to reach end-point output readings. Participant B and C (when immobilised) and participant HH (when non-immobilised) demonstrate this lag in oxygen uptake, total energy cost and relative energy expenditure data (see Appendix 1). To investigate this further, the time to reach half of the end-point oxygen uptake, total energy cost and relative energy expenditure for each participant was determined (see Table 5). Heart rate data could not be utilised in this manner as for every participant the half end-point heart rate value was less than their initial resting heart rate measurement. The time it took an individual (immobilised or non-immobilised) to reach half maximum output readings varied, ranging from one second to close to one minute. As the apparatus sampled at a non-uniform rate and the data was relatively “noisy”, the readings are the closest approximation to the time at which half end-point readings were met. The times to reach half the end-point readings within the immobilised and non-immobilised groups were within thirty seconds of each other, for all but one participant. Participant B demonstrates a much greater time to reach half end-point value in the immobilised group (56 seconds longer) than in the non-immobilised group (see Table 5).

[Insert Table 5 here]
4. **Discussion**

The objective of this study was to measure the effect of immobilisation of an upper limb on various physiological parameters during the everyday task of stair climbing. Following the stair climbing task, only a *trivial* to *small* difference in the immobilised and non-immobilised groups was demonstrated. These results are in agreement with previous studies by Chapman & Ralston (1964), Park et al. (2000) and Hanada & Kerrigan (2001), all of which illustrated that unilateral immobilisation of an upper limb during a level walking task had no effect on total energy cost.

Greenman (1996, p. 11) suggests that a musculoskeletal dysfunction places a greater demand on the individual as the dysfunction requires greater musculoskeletal activity and therefore imparts a greater energetic cost. Therefore having an individual complete an exercise task that imposes a further metabolic cost, such as climbing a set of stairs, requires additional energy demand for which the musculoskeletal system has difficulty compensating for. In our study however, a greater energetic cost could not be detected by imposing a musculoskeletal dysfunction through immobilisation of an upper limb during stair climbing at 80 steps.min$^{-1}$. The hypothesis of Greenman (1996, p. 11) is indeed true when the musculoskeletal dysfunction occurs in a joint of the lower extremity. Not only has the increase in energetic cost been outlined by Greenman himself, who states that restriction of one major joint in the lower extremity can increase energy expenditure by up to 40% and restriction of two major joints in the same lower extremity by up to 300% (Greenman, 1996, p. 11), but Hanada & Kerrigan (2001), Abdulhadi, Kerrigan, & LaRaia (1996) and Mattsson & Brostrom (1990) all demonstrated increases in oxygen uptake when healthy participants had an imposed immobilisation of a knee or ankle joint. The influence of hip musculoskeletal dysfunction on the energetic cost has been demonstrated in studies by Waters, Barnes, Husserl, Silver, & Liss (1988) and Mattsson (1989). Waters et al. (1988) found a 32% increase in oxygen consumption in patients with unilateral hip arthrodesis compared to the asymptomatic control group and Mattsson (1989) reported that at a one year follow-up of patients who had a total hip replacement, their oxygen uptake during a level walking task decreased from 0.27 L/kg/min$^{-1}$ to 0.22 L.kg.min$^{-1}$. 
A large effect is observed pre- to post- stair climbing for oxygen uptake, heart rate, total energy cost and relative energy expenditure, showing that the physiological measures of oxygen uptake, heart rate, total energy cost and relative energy expenditure all considerably increase during the stair climbing task. The increase in values as a result of an exercise task is consistent with texts by previous authors (Bray, et al., 1986, p. 240; Guyton & Hall, 2000, p. 110; Marieb, 2004, p. 664; Wilmore, et al., 2008, p. 440).

Physiological values prior to the stair climbing task are similar in both the immobilised and non-immobilised groups. A trivial to small difference in the immobilised and non-immobilised groups prior to the stair climbing task can be seen. A trivial to small difference between the immobilised and non-immobilised groups prior to the stair climbing task indicates that the participants had returned to resting values before beginning the subsequent exercise task. The fact that only such a negligible difference is seen in prior physiological values may indicate that the rest period of 15 to 45 minutes was adequate.

On closer inspection of the individual participant’s mean data, it was noted that approximately half of the participants showed higher outcome measure values in the immobilised stair climbing task than the non-immobilised task. However, the majority demonstrated greater outcome measure values in the second stair climbing task in respect to the first task, based on observation of mean and individual data. This posed the question of whether the order of immobilisation had an effect on the results, regardless of whether the upper limb was freely moving or immobilised. Therefore, it is interesting that majority of the participants found the second stair climbing task harder than the first as analysis of mean data shows that order of immobilisation has a trivial to small effect.

In contrast, four participants showed greater outcome measure values in the first stair climbing task than the second. For three of these participants (U, EE, and GG) the arm was immobilised for the first exercise, while for participant R both arms moved freely (see Appendix 2 for data). There are some noticeable similarities and differences between these four participants and all others in the study. Two were male, two were
female, and all were aged between 19 and 26 years, which fits with the demographics of the remaining participants. All four participants classified themselves as presently moderately active with a moderate level of fitness. The only apparent point of difference was that one of the four was a regular smoker (approximately 15 cigarettes per day), of which there was only six others in the sample population. Further to these identified differences, variation in the data of these four participants may be due to an uncontrolled variable such as anxiety or prior exercise. In light of these details, it remains unclear as to why these four participants found the first task stair climbing task more physiologically challenging.

Observation of individual data plots shows a lag, or delay, in time to reach half end-point oxygen uptake in the immobilised data set for participants B and C and in the non-immobilised data set of participant HH. An early study by Craig (1972) suggests that an observed lag in oxygen uptake could be a delay in intramuscular vasodilatation in exercising skeletal muscle, therefore limiting the supply of oxygen to the muscle. Though, studies by Tschakovsky & Hughson (1999); Savard, Nielsen, Laszczynska, Larsen, & Saltin (1988) and Nielsen, Savard, Richter, Hargreaves, & Saltin (1990) to name a few, and the recent study by Nyberg, Mortensen, Saltin, Hellsten and Bangsbo (2010) suggest that muscle blood flow does not limit oxygen uptake during the initial stages of moderate intensity exercise. Grassi et al. (1996) describes oxygen uptake during moderate intensity work as a three phase process. The increase in oxygen uptake during the first two phases represents the circulatory system’s ability to deliver oxygen, and the cells ability to utilise oxygen. A lag or slowing in the oxygen kinetics in these two phases would limit the transportation and utilisation of oxygen in exercising skeletal muscle. Further, it is conceivable that immobilisation of an upper limb could result in an impaired rib expansion, limiting the amount of inhaled oxygen rich air, and therefore reducing the oxygen available to exercising skeletal muscle. Even though such oxygen kinetic and biomechanic arguments seem plausible, only two participants in the immobilised group show this lag, while only one demonstrates the same effect in the non-immobilised group. The reason as to why a difference is observed in these three participants remains unclear.
**Limitations**

The exercise task set in this study may not have been intense enough to show a potential difference in energetic costs between dysfunctional and functional as would be predicted by Greenman (1996, p. 11). Other studies used level walking at a faster stepping rate than this study and reported a greater energetic cost when the upper limb is immobilised (Park, et al., 2000; Umberger, 2008).

This study may be further limited as only the values at the conclusion of the stair climb were used in the analysis to determine any potential effect of dysfunction on the final energetic cost of stair climbing. Consideration of the time taken to reach these values rather than the end-point values themselves may be more representative of the energetic burden of the exercise task. The time to reach half end-point value can be calculated using equipment capable of accurate real time analysis and would be informative in future studies. Additionally, it may be more informative to measure the time to reach end-point outcome measures in order to determine subtle differences in the immobilised and non-immobilised groups.

As each participant did not repeat the stair climbing task in the reverse order and that immobilisation of the upper limb was not standardised across the participants these factors act as limitations to the study design. These limitations within the study design became apparent post data collection. More accurate conclusions regarding the effect of upper limb immobilisation during a stair climbing task could be drawn if the study design had required the immobilised stair climbing task to be conducted both first (followed by climbing with the upper limbs freely moving) and second (preceded by climbing with the upper limbs freely moving). This study randomly assigned which of the participant’s upper limbs was immobilised. This condition should be standardised in future studies.

Practical constraints in this study meant that the rest period between trials (immobilised and non-immobilised) was not consistent between participants. This time varied from 15 to 45 minutes. A 15 minute rest period may have been inadequate for some (or all) participants, and fatigue, either central and/or peripheral, may have had an impact on the
second trial (Stokes, Cooper, & Edwards, 1988). Fatigue may explain the observation that the majority of the participants found the second stair climbing task more energetically demanding. Although, a trivial to small difference was observed across the four outcome variables prior to the exercise task indicating that a considerable number of participants had outcome measure values pre-stair climb that were similar at the onset of the first and second exercise tasks. A longer rest period would account for any increase in metabolic by-products as a result of the first task.

Prior physical activity of any of the participants before the experimental trial would plausibly influence the data. This variable was not adequately controlled in this study.
5. Conclusion

In this sample population, within the limitations of this study, it can be concluded that immobilisation of the upper limb has only a *trivial to small effect* on oxygen uptake, heart rate, total energy cost, and relative energy expenditure during a stair climbing task. This study therefore does not show any meaningful relationship between minor dysfunction (immobilisation of arm) and an increased metabolic demand hypothesised by Greenman (1996, p. 11).
Figure 1. A research participant wearing the Metamax 3B Cardiopulmonary system
Figure 2. The Metamax 3B cardiopulmonary system data receiver (foreground) and the Metasoft programme running on the computer (background)
Figure 3. A research participant wearing the Metamax 3B Cardiopulmonary system with their upper limb immobilised by a sling
Table 1. Changes in physiological parameters within the immobilised and non immobilised groups pre- to post-stair climb.

<table>
<thead>
<tr>
<th></th>
<th>oxygen uptake (L.min⁻¹.kg⁻¹)</th>
<th>heart rate (beats.min⁻¹)</th>
<th>total energy cost (kcal.d⁻¹)</th>
<th>relative energy expenditure (kcal.d⁻¹.kg⁻¹)</th>
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</thead>
<tbody>
<tr>
<td><strong>Non-Immobilised</strong></td>
<td></td>
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</tr>
<tr>
<td>PRE</td>
<td>0.5 ± 0.2</td>
<td>103 ± 19</td>
<td>3711 ± 1555</td>
<td>53 ± 23</td>
</tr>
<tr>
<td>POST</td>
<td>1.9 ± 0.5</td>
<td>161 ± 16</td>
<td>13568 ± 3507</td>
<td>192 ± 39</td>
</tr>
<tr>
<td>Mean Diff</td>
<td>72.3</td>
<td>36.2</td>
<td>72.6</td>
<td>72.2</td>
</tr>
<tr>
<td>Upper CL</td>
<td>72.3</td>
<td>36.2</td>
<td>72.6</td>
<td>72.2</td>
</tr>
<tr>
<td>Lower CL</td>
<td>72.3</td>
<td>36.2</td>
<td>72.6</td>
<td>72.2</td>
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<tr>
<td>Magnitude</td>
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<td>Large</td>
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<tr>
<td><strong>Likelihood of Difference</strong></td>
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<tr>
<td>Negative</td>
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<td>100</td>
<td>100</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td><strong>Immobilised</strong></td>
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<td></td>
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</tr>
<tr>
<td>PRE</td>
<td>0.5 ± 0.2</td>
<td>106 ± 14</td>
<td>3362 ± 1419</td>
<td>48 ± 21</td>
</tr>
<tr>
<td>POST</td>
<td>1.9 ± 0.4</td>
<td>165 ± 18</td>
<td>13861 ± 2717</td>
<td>198 ± 35</td>
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<tr>
<td>Mean Diff</td>
<td>73.7</td>
<td>35.6</td>
<td>75.7</td>
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<tr>
<td>Upper CL</td>
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<td>Positive</td>
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</table>

**Note:**
1. Values are mean ± standard deviation.
2. PRE= prior to stair climb; POST= at the conclusion of the stair climb.
3. Difference between groups (expressed as a percent).
4. CL = 95% Confidence Limits (expressed as a percent).
5. Magnitude of the effect based on Cohen (1988, p. 71) and Hopkins (2009) expresses the differences between the immobilised and non-immobilised groups
6. Likelihood of difference, or clinical likelihood as indicated by Hopkins (2009) are expressed as a percent chance that the true differences between the immobilised and non immobilised groups are either that; the non immobilised task is more challenging in each of the four outcome variables (negative), that the immobilised task is more challenging, though the difference is negligible (trivial), or that the immobilised task demonstrates a substantial difference (positive).
Table 2. Differences in physiological parameters between the immobilised and non-immobilised groups prior to the stair climb.

<table>
<thead>
<tr>
<th>Outcome measures</th>
<th>NI $^1$</th>
<th>I $^1$</th>
<th>Mean Diff $^2$</th>
<th>Upper CL $^3$</th>
<th>Lower CL $^3$</th>
<th>Magnitude $^4$</th>
<th>Likelihood of Difference $^5$</th>
</tr>
</thead>
<tbody>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Negative</td>
</tr>
<tr>
<td>oxygen uptake (L.min$^{-1}$.kg$^{-1}$)</td>
<td>0.5 ± 0.2</td>
<td>0.5 ± 0.2</td>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
<td>Trivial</td>
<td>0</td>
</tr>
<tr>
<td>heart rate (beats.min$^{-1}$)</td>
<td>103 ± 19</td>
<td>106 ± 14</td>
<td>3.5</td>
<td>7.6</td>
<td>-0.6</td>
<td>Small</td>
<td>0</td>
</tr>
<tr>
<td>total energy cost (kcal.d$^{-1}$)</td>
<td>3711 ± 1555</td>
<td>3362 ± 1419</td>
<td>9.4</td>
<td>20.7</td>
<td>-1.9</td>
<td>Small</td>
<td>0</td>
</tr>
<tr>
<td>relative energy expenditure (kcal.d$^{-1}$.kg$^{-1}$)</td>
<td>53 ± 23</td>
<td>48 ± 21</td>
<td>9.8</td>
<td>21.6</td>
<td>-2.0</td>
<td>Small</td>
<td>1</td>
</tr>
</tbody>
</table>

Note:
1. Values are mean ± standard deviation. NI = Non-Immobilised Group; I = Immobilised Group.
2. Difference between groups (expressed as a percent).
3. CL = 95% Confidence Limits (expressed as a percent).
5. Likelihood of difference, or clinical likelihood as indicated by Hopkins (2009) are expressed as a percent chance that the true differences between the immobilised and non-immobilised groups are either that; the non immobilised task is more challenging in each of the four outcome variables (negative), that the immobilised task is more challenging, though the difference is negligible (trivial), or that the immobilised task demonstrates a substantial difference (positive).
Table 3. Overall differences between immobilised and non immobilised groups in physiological parameters measured post-stair climb.

<table>
<thead>
<tr>
<th>Outcome measures</th>
<th>NI $^{1}$</th>
<th>I $^{1}$</th>
<th>Mean Diff $^{2}$</th>
<th>Upper CL $^{3}$</th>
<th>Lower CL $^{3}$</th>
<th>Magnitude $^{4}$</th>
<th>Likelihood of Difference $^{5}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>oxygen uptake (L.min$^{-1}$.kg$^{-1}$)</td>
<td>1.37 ± 0.54</td>
<td>1.39 ± 0.43</td>
<td>0.63</td>
<td>6.9</td>
<td>-5.7</td>
<td>Trivial</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>75</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>heart rate (beats.min$^{-1}$)</td>
<td>58 ± 16</td>
<td>59 ± 16</td>
<td>2.7</td>
<td>2.7</td>
<td>2.7</td>
<td>Small</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>total energy cost (kcal.d$^{-1}$)</td>
<td>9858 ± 3560</td>
<td>10499 ± 3062</td>
<td>2.1</td>
<td>8.8</td>
<td>-4.6</td>
<td>Trivial</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>64</td>
<td>32</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>relative energy expenditure (kcal.d$^{-1}$.kg$^{-1}$)</td>
<td>139 ± 42</td>
<td>149 ± 39</td>
<td>2.6</td>
<td>9.5</td>
<td>-4.3</td>
<td>Trivial</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>59</td>
<td>37</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note:
1. Values are mean ± standard deviation. NI = Non-Immobilised Group; I = Immobilised Group.
2. Difference between groups (expressed as a percent).
3. CL = 95% Confidence Limits (expressed as a percent).
5. Likelihood of difference, or clinical likelihood as indicated by Hopkins (2009) are expressed as a percent chance that the true differences between the immobilised and non immobilised groups are either that; the non immobilised task is more challenging in each of the four outcome variables (negative), that the immobilised task is more challenging, though the difference is negligible (trivial), or that the immobilised task demonstrates a substantial difference (positive).
Table 4. Mean differences in order of immobilisation and dominance between the immobilised and non-immobilised groups.

<table>
<thead>
<tr>
<th></th>
<th>NI $^1$</th>
<th>I $^1$</th>
<th>Effect Size $^2$</th>
<th>Magnitude of Effect $^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>oxygen uptake (L.min$^{-1}$.kg$^{-1}$)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NI/I</td>
<td>23 ± 5</td>
<td>23 ± 6</td>
<td>0</td>
<td>no effect</td>
</tr>
<tr>
<td>NI/I DOM</td>
<td>23 ± 5</td>
<td>25 ± 5</td>
<td>0.40</td>
<td>small</td>
</tr>
<tr>
<td>NI/I NON DOM</td>
<td>23 ± 5</td>
<td>22 ± 6</td>
<td>0.19</td>
<td>trivial</td>
</tr>
<tr>
<td>I/NI</td>
<td>26 ± 6</td>
<td>26 ± 6</td>
<td>0</td>
<td>no effect</td>
</tr>
<tr>
<td>I/NI DOM</td>
<td>25 ± 6</td>
<td>26 ± 6</td>
<td>0.17</td>
<td>trivial</td>
</tr>
<tr>
<td>I/NI NON DOM</td>
<td>26 ± 6</td>
<td>26 ± 6</td>
<td>0</td>
<td>no effect</td>
</tr>
<tr>
<td><strong>heart rate (beats.min$^{-1}$)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NI/I</td>
<td>146 ± 14</td>
<td>152 ± 13</td>
<td>0.43</td>
<td>small</td>
</tr>
<tr>
<td>NI/I DOM</td>
<td>146 ± 14</td>
<td>152 ± 13</td>
<td>0.43</td>
<td>small</td>
</tr>
<tr>
<td>NI/I NON DOM</td>
<td>146 ± 14</td>
<td>153 ± 13</td>
<td>0.50</td>
<td>moderate</td>
</tr>
<tr>
<td>I/NI</td>
<td>150 ± 15</td>
<td>154 ± 17</td>
<td>0.25</td>
<td>small</td>
</tr>
<tr>
<td>I/NI DOM</td>
<td>145 ± 14</td>
<td>154 ± 17</td>
<td>0.56</td>
<td>moderate</td>
</tr>
<tr>
<td>I/NI NON DOM</td>
<td>154 ± 17</td>
<td>154 ± 17</td>
<td>0.00</td>
<td>no effect</td>
</tr>
<tr>
<td><strong>total energy cost (kcal.d$^{-1}$)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NI/I</td>
<td>11550 ± 2675</td>
<td>11771 ± 2943</td>
<td>0.08</td>
<td>trivial</td>
</tr>
<tr>
<td>NI/I DOM</td>
<td>11550 ± 2675</td>
<td>11485 ± 2695</td>
<td>0.02</td>
<td>trivial</td>
</tr>
<tr>
<td>NI/I NON DOM</td>
<td>11550 ± 2675</td>
<td>12058 ± 3191</td>
<td>0.17</td>
<td>trivial</td>
</tr>
<tr>
<td>I/NI</td>
<td>12843 ± 3140</td>
<td>12936 ± 3083</td>
<td>0.03</td>
<td>trivial</td>
</tr>
<tr>
<td>I/NI DOM</td>
<td>12843 ± 3140</td>
<td>11946 ± 2888</td>
<td>0.29</td>
<td>small</td>
</tr>
<tr>
<td>I/NI NON DOM</td>
<td>12843 ± 3140</td>
<td>13925 ± 3279</td>
<td>0.34</td>
<td>small</td>
</tr>
<tr>
<td><strong>relative energy expenditure</strong> (kcal.d$^{-1}$.kg$^{-1}$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NI/I</td>
<td>164 ± 39</td>
<td>167 ± 42</td>
<td>0.08</td>
<td>trivial</td>
</tr>
<tr>
<td>NI/I DOM</td>
<td>164 ± 39</td>
<td>176 ± 42</td>
<td>0.3</td>
<td>small</td>
</tr>
<tr>
<td>NI/I NON DOM</td>
<td>164 ± 39</td>
<td>157 ± 42</td>
<td>0.18</td>
<td>trivial</td>
</tr>
<tr>
<td>I/NI</td>
<td>184 ± 45</td>
<td>184 ± 44</td>
<td>0</td>
<td>no effect</td>
</tr>
<tr>
<td>I/NI DOM</td>
<td>184 ± 45</td>
<td>182 ± 44</td>
<td>0.05</td>
<td>trivial</td>
</tr>
<tr>
<td>I/NI NON DOM</td>
<td>184 ± 45</td>
<td>187 ± 44</td>
<td>0.07</td>
<td>trivial</td>
</tr>
</tbody>
</table>

Note:
1. Values are mean ± standard deviation. NI = Non-Immobilised Group; I = Immobilised Group.
2. Effect size and magnitude of the effect are interpreted based on the criteria by Cohen (1988, p. 71) and Hopkins (2009), expressing the difference between the immobilised and non-immobilised groups.
3. NI/I - non immobilisation followed by immobilisation (including either the dominant or the non dominant arm)
4. NI/I DOM - non immobilisation followed by immobilisation of the dominant arm
5. NI/I NON DOM - non immobilisation followed by immobilisation of the non dominant arm
6. I/NI - immobilisation (either the dominant or non dominant arm) followed by non immobilisation
7. I/NI DOM - immobilisation of the dominant arm followed by non immobilisation
8. I/NI NON DOM - immobilisation of the non dominant arm followed by non immobilisation
Table 5. Time to reach half end-point readings for immobilised and non-immobilised groups represented as one value for oxygen uptake, total energy cost and relative energy expenditure

<table>
<thead>
<tr>
<th>Participant</th>
<th>NI ¹</th>
<th>I ²</th>
<th>Difference ³</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>00.01.13</td>
<td>00.00.54</td>
<td>-00.00.19</td>
</tr>
<tr>
<td>B</td>
<td>00.00.31</td>
<td>00.01.28</td>
<td>00.00.56</td>
</tr>
<tr>
<td>C</td>
<td>00.01.33</td>
<td>00.01.55</td>
<td>00.00.22</td>
</tr>
<tr>
<td>D</td>
<td>00.00.06</td>
<td>00.00.24</td>
<td>00.00.18</td>
</tr>
<tr>
<td>E</td>
<td>00.00.41</td>
<td>00.00.40</td>
<td>-00.00.01</td>
</tr>
<tr>
<td>F</td>
<td>00.00.39</td>
<td>00.00.36</td>
<td>-00.00.03</td>
</tr>
<tr>
<td>G</td>
<td>00.00.18</td>
<td>00.00.35</td>
<td>00.00.17</td>
</tr>
<tr>
<td>H</td>
<td>00.00.15</td>
<td>00.00.20</td>
<td>00.00.05</td>
</tr>
<tr>
<td>I</td>
<td>00.00.38</td>
<td>00.00.18</td>
<td>-00.00.20</td>
</tr>
<tr>
<td>J</td>
<td>00.00.42</td>
<td>00.00.41</td>
<td>-00.00.01</td>
</tr>
<tr>
<td>K</td>
<td>00.00.44</td>
<td>00.00.23</td>
<td>-00.00.21</td>
</tr>
<tr>
<td>L</td>
<td>00.00.28</td>
<td>00.00.39</td>
<td>00.00.11</td>
</tr>
<tr>
<td>M</td>
<td>00.00.27</td>
<td>00.00.35</td>
<td>00.00.08</td>
</tr>
<tr>
<td>N</td>
<td>00.00.19</td>
<td>00.00.25</td>
<td>00.00.06</td>
</tr>
<tr>
<td>O</td>
<td>00.00.38</td>
<td>00.00.27</td>
<td>-00.00.11</td>
</tr>
<tr>
<td>P</td>
<td>00.00.15</td>
<td>00.00.09</td>
<td>-00.00.06</td>
</tr>
<tr>
<td>Q</td>
<td>00.00.34</td>
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<td>-00.00.06</td>
</tr>
<tr>
<td>R</td>
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<td>00.01.01</td>
<td>00.00.28</td>
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<tr>
<td>S</td>
<td>00.00.32</td>
<td>00.00.38</td>
<td>00.00.06</td>
</tr>
<tr>
<td>T</td>
<td>00.00.42</td>
<td>00.00.37</td>
<td>-00.00.05</td>
</tr>
<tr>
<td>U</td>
<td>00.00.24</td>
<td>00.00.29</td>
<td>00.00.05</td>
</tr>
<tr>
<td>V</td>
<td>00.00.37</td>
<td>00.00.35</td>
<td>-00.00.02</td>
</tr>
<tr>
<td>W</td>
<td>00.00.10</td>
<td>00.00.24</td>
<td>00.00.14</td>
</tr>
<tr>
<td>Y</td>
<td>00.00.28</td>
<td>00.00.38</td>
<td>00.00.10</td>
</tr>
<tr>
<td>Z</td>
<td>00.00.27</td>
<td>00.00.40</td>
<td>00.00.13</td>
</tr>
<tr>
<td>AA</td>
<td>00.00.40</td>
<td>00.00.32</td>
<td>-00.00.08</td>
</tr>
<tr>
<td>BB</td>
<td>00.00.29</td>
<td>00.00.33</td>
<td>00.00.04</td>
</tr>
<tr>
<td>CC</td>
<td>00.00.28</td>
<td>00.00.39</td>
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<tr>
<td>DD</td>
<td>00.00.29</td>
<td>00.00.20</td>
<td>-00.00.09</td>
</tr>
<tr>
<td>EE</td>
<td>00.01.00</td>
<td>00.01.01</td>
<td>00.00.01</td>
</tr>
<tr>
<td>FF</td>
<td>00.00.36</td>
<td>00.00.21</td>
<td>-00.00.15</td>
</tr>
<tr>
<td>GG</td>
<td>00.00.32</td>
<td>00.00.21</td>
<td>-00.00.11</td>
</tr>
<tr>
<td>HH</td>
<td>00.00.25</td>
<td>00.00.26</td>
<td>00.00.01</td>
</tr>
</tbody>
</table>

Note:
1. Pelto et al. (1989) state that energy expenditure is dependent upon oxygen uptake. Therefore, each participant the times to reach half end-point oxygen uptake, energy and relative energy expenditure values are shown as one value.
2. Values are time, expressed as hours.minutes.seconds. NI = non-immobilised condition; I = immobilised condition.
3. Difference is expressed as the immobilised time value minus non-immobilised value.
References


Appendix One

**Oxygen uptake**

**Heart Rate**

**Total Energy Cost**

**Relative Energy Expenditure**

---

No or incomplete data
Oxygen uptake

Heart Rate

Total Energy Cost

Relative Energy Expenditure

No or incomplete data
Oxygen uptake

Heart Rate

Total Energy Cost

Relative Energy Expenditure

Participant Z

Participant AA

Participant BB
Appendix Two

### Oxygen Uptake

- **Time (hh:mm:ss)**
- **Oxygen Uptake (ml.kg.min)**

### Heart Rate

- **Time (hh:mm:ss)**
- **Heart Rate (beats.min)**

### Total Energy Cost

- **Time (hh:mm:ss)**
- **Total Energy Cost (kcal.d)**

### Relative Energy Expenditure

- **Time (hh:mm:ss)**
- **Relative Energy Expenditure (kcal.d.kg)**

---

Non Immobilised
---

Log. (Immobilised)
---

Log. (Non Immobilised)
Oxygen Uptake

Heart Rate

Total Energy Cost

Relative Energy Expenditure
Appendix Three

Consent Form for Participants
Effect of unilateral immobilization of the upper extremity on O$_2$ consumption, heart rate and energy cost in stair climbing

Participating in this study requires you to climb up a set of stairs to a metronome beat for five minutes under two experimental conditions, where your arms are swinging freely by your side as they would when you normally climb stairs, and with one of your arms immobilised using a sling. During the trials, your heart rate and expired air volume will be measured, using a heart rate monitor placed around your chest, and by breathing into an apparatus throughout the duration of the trial. Between trials you will have a 15 minute rest period to ensure you return to baseline measures. On each climb will be accompanied by the researcher to ensure that you follow the climbing beat, take one step at a time, not use the handrail or stop at any time during the experiment. Additional information regarding your age, height and weight will be recorded before beginning the study.

This research is being conducted by Kirsty Richardson from the Masters of Osteopathy at Unitec Institute of Technology, and will be supervised by Associate Professor Andy Stewart and Dr Graham Fordy. Findings from this research will be used to complete the Master of Osteopathy degree and may be used within a published journal article.

Name of Participant: .................................................................

I have seen the Information Sheet for participants taking part in the above Masters study. I have had the opportunity to read the contents of the information sheet and to discuss the study with the researching team and I am satisfied with the explanations I have been given. I understand that taking part in this study is voluntary, that I can withdraw from the study up to two weeks post data collection, and that no data gained from the study can lead to my identification so that my anonymity is preserved.

I understand that I can withdraw from the trial without any consequence if, for any reason, I want to.

I understand that my participation in this study is confidential and that no data or information gained could breach this confidentiality.

I have read and understood the health screening questionnaire and details given are accurate to my knowledge.

I have no history of thrombosis, asthma which has required hospitalization in the last five years, gait disorders, upper motor neuron disease, cardiovascular disease, respiratory disease or rheumatological conditions which would exclude me from this study.

I have had enough time to consider whether I want to take part.

I know whom to contact if I have any questions or concerns about the study.

The principal researcher for this study is Kirsty Richardson, who is contactable via email at kirstyleerichardson@gmail.com. The supervisor, Associate Professor Andy Stewart can be contacted via email at astewart@unitec.ac.nz

Signature of Participant.............................................................. ............(date)

Study explained by.................................................................

Signature of Researcher ............................................................ ............(date)

This study has been approved by the Unitec Research Ethics Committee from June 2008 to December 2009, approval number 862. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the UREC Secretariat (Ph: 09 815-4321 ext 7254). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.
Information Sheet for Participants

Effect of unilateral immobilization of the upper extremity on O₂ consumption, heart rate and energy cost in stair climbing

Introduction
I am a Masters of Osteopathy student, who is currently undertaking research as part of my course requirements. I am doing research on the effect of unilateral upper extremity immobilization on oxygen consumption, heart rate and energy cost of stair climbing. My aims are to see if immobilisation has any effect on each of these parameters, and the possible implications of immobilisation when exercising. This will be achieved by individuals walking up stairs for five minutes with their arms swinging freely, and then repeated with one of their arms movement being restricted by a sling.

What is being asked of you?
This study requires you to walk up a flight of stairs twice, five minutes each time, once with your arms swinging freely then with one arm being immobilized, with a rest period of 15 minutes between trials. During the trial, you will have your heart rate measured by a device placed around your chest and your expired air volume by breathing into a mouthpiece. You will be accompanied on your climb to ensure that you follow the guidelines of the trial, following the climbing beat, taking one step at a time, not using the handrail or stop at any time during the experiment. You will be randomly allocated to which trial you complete first dependent on your registration to the study. Additional information regarding your age, height and weight will be recorded before beginning the study.

What does this mean for you as a participant?
- You have to be walking more than one flight of stairs at least once a week as part of your everyday living, be pain-free during walking, and have no existing shoulder complaint or injury, or had a complaint or injury over the last year.
- You cannot participate if you have any gait disorders, upper motor neuron disease, cardiovascular or respiratory disease or rheumatological conditions.
- You cannot participate if you have a history of thrombosis, or asthma which has required hospitalization in the last five years.
- Participation is your choice, and you have the option to withdraw from the study up to two weeks post data collection, with no consequences.
- Data gained doesn’t require you to supply any personal information that could lead to your identification, so your confidentiality is preserved.
- You are free to contact the researcher regarding any concerns or queries.
- Data gained from this research will be used for submission of a Masters of Osteopathy thesis and may be used within a published journal article following the completion of the Masters degree.

Confidentiality
The researcher aims to ensure that the information you have given is kept confidential. Data retrieved from the trial will be numbered, keeping the results confidential and will be entered within a computer programme that only the researcher and her supervisors can access. Raw copies of the data will be stored for five years following the study and will then be destroyed.

Consent
This information will be repeated to you before the commencement of the study with an opportunity for you to clear any doubts or concerns. Both verbal and written consent will be gained from you and it is taken as an indication that you consent to participate in this study.

Thank you very much for your participation. If you have any questions or enquires at any time during the course of the study or following the completion of the study, please don’t hesitate to contact me or my supervisor via email at kirstyleerichardson@gmail.com or astewart@unitec.ac.nz.

This study has been approved by the Unitec Research Ethics Committee from June 2008 to December 2009, approval number 862. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the UREC Secretariat (Ph: 09 815-4321 ext 7254). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.
Health Screening Questionnaire

Effect of unilateral immobilization of the upper extremity on $O_2$ consumption, heart rate and energy cost in stair climbing

Name: ___________________________________________  Date of Birth: _______________________

Activity Status:
How would you describe your present level of activity? (Please circle)

Sedentary  Moderate  Active  Highly Active

How would you describe your level of fitness? (Please circle)

Unfit  Moderate  Fit  Trained

Medical Status:
1. Do you have a history of cardiovascular or respiratory disorder?  Y / N
2. Do you have a history of high blood pressure?  Y / N
3. Do you suffer from dizziness?  Y / N
4. Do you suffer from thrombosis?  Y / N
5. Do you have a previous/current injury that may impede your ability to exercise?  Y / N
6. Have you consulted a doctor in the last 6 months for exercise related reasons?  Y / N
7. Are you currently taking any form of medication?  Y / N
8. Have you ever suffered from asthma which required hospitalization in the last five years?  Y / N
9. Do you suffer from any gait disorders, which impedes your ability to walk?  Y / N
10. Do you suffer from any rheumatological condition (e.g., osteoarthritis, rheumatoid arthritis)?  Y / N
11. Do you suffer from an upper motor neuron disease (e.g., multiple sclerosis)?  Y / N

If you have answered YES to any of the above, please give details below:

-------------------------------------------------------------------------------------------

Smoking habits: (Please circle)
Never
Used to Smoke  How many/day?  --------
Occasionally Smoke  How many/day?  --------
Regularly Smoke  How many/day?  --------

Declaration

I declare that all information given above has been read, understood and is correct to the best of my knowledge.

Signature: ___________________________________________  Date: _________________________
Appendix Four

Submission Criteria for Gait and Posture: Guide for Authors

Official Journal of: Gait and Clinical Movement Analysis Society (GCMAS), European Society of Movement Analysis in Adults and Children (ESMAC), Società Italiana di Analisi del Movimento in Clinica (SIAMOC), and the International Society for Posture and Gait Research (ISPGR).

Authors should submit online http://ees.elsevier.com/gaipos. This is the Elsevier web-based submission and review system. You will find full instructions located on this site in the Tutorial for Authors. Please follow the guidelines to prepare and upload your article. Once the uploading is done, the system automatically creates an electronic pdf which is used for reviewing. All correspondence, including notification of the Editor's decision and requests for revisions, will be managed via this system.

A manuscript submitted to this journal can only be published if it (or a similar version) has not been published and will not be simultaneously submitted or published elsewhere. A violation of this condition is considered fraud, and will be addressed by appropriate sanctions. Two manuscripts are considered similar if they concern the same hypothesis, question or goal, using the same methods and/or essentially similar data.

Preparation of the Manuscript

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